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E. C. AUCHTER

CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior

*As revised and adopted at the Philadelphia meeting, January 1, 1941.

branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings,

RESUMÉ OF THE 1942 MEETING OF THE WESTERN SECTION

The Western Section met for its fourth annual meeting at the University of Utah, Salt Lake City, on June 17, 18, and 19, 1942. The Society participated in four symposias, and 23 papers were presented at other sessions. Attendance was good, with 37 present to hear the address of Dr. W. W. Aldrich on "Irrigation in Horticulture Today". Dr. Aldrich summarized present knowledge on this subject for a wide range of horticultural plants and climatic and soil conditions. He discussed these data from the standpoint of methods which may be used to determine when horticultural plants should be irrigated. Some interesting comments were made by Professor Eustace and Judge Howell. Dr. S. T. Shaw and the local committee made excellent arrangements for the meeting and the annual dinner.

The officers elected for 1942-43 are: Chairman, Henry Hartman; Vice-Chairman, John H. MacGillivray; and Secretary, C. L. Vincent. The 1943 meeting will be held at Corvallis, Oregon.

The Phosphate Nutrition of Fruit Trees IV. The Phosphate Content of Peach Leaves from 130 Orchards in California and Some Factors Which May Influence It

By OMUND LILLELAND and J. G. BROWN, *University of California, Davis, Calif.*

FOR several years we have been studying the growth and response of fruit trees to phosphate on the low phosphate Aiken clay loam at Paradise, California. In June and July 1940 we sampled leaves from 130 commercial peach orchards to study their potassium content as reported in (1). An opportunity was thus afforded to also learn from these orchards what the average level of phosphorus might be in such a wide and representative sampling of California peach trees, and to compare these leaf data with the phosphorus analyses from our experimental plots on the low Aiken soil.

THE SEASONAL TREND OF PHOSPHORUS AND ITS RELATION TO TIME OF SAMPLING

The percentage of phosphorus in the dry leaf matter decreases sharply during spring and early summer and then remains fairly constant until the peach leaves turn yellow in the fall when there appears to be a movement of the phosphorus back into the tree. Samples taken from the same trees in June, July and August for a number of years have shown the phosphorus percentage to be practically constant during this interim. Table I shows that samples of basal leaves on current growth, taken in April, are distinctly high. The May samples show a lower percentage of phosphorus and the June data a further decrease.

TABLE I—SEASONAL TREND OF PHOSPHORUS IN PEACH LEAVES (VARIETY ELBERTA)*

Plot Description	Year	Per Cent P in Dry Leaf Matter						
		Apr	May	Jun	Jul	Aug	Sep	Oct
1. Planted 1934 low phosphate† soil, Aiken clay loam, Ream orchard, Paradise	1941	0.54	—	0.15	—	0.13	—	—
	1939	—	—	0.15	0.13	0.14	—	—
	1937	—	—	0.11	0.11	—	—	—
	1935	—	—	0.15	—	0.11	0.12	0.13
2. Planted 1938 Ream orchard, Paradise	1941	0.53	—	0.15	—	0.12	—	—
	1940	—	0.18	0.13	—	—	—	—
3. Planted 1939 Ream orchard, Paradise	1941	—	—	0.24	0.08	0.09	—	—
4. Planted 1940 high phosphate† soil, Yolo loam, Wolfskill orchard	1941	—	0.30	0.13	—	0.12	—	—
5. Planted 1940 high phosphate† soil, Yolo loam, University Farm, Davis	1941	—	—	0.30	0.31	0.29	—	—
6. Planted 1922 University Farm, Davis	1940	—	0.23	0.17	0.16	0.16	—	—

*Sampling in all cases was limited to basal leaves on current growth.

†Neubauer rye seedling method gives the following analyses: Ream orchard, Aiken clay loam—3 parts per million P in soil (0 to 4 foot depth); Wolfskill orchard, Yolo loam—23 parts per million P in soil (0 to 4 foot depth); and University Farm, Yolo loam—27 parts per million P in soil (0 to 4 foot depth).

However, with the possible exception of plot No. 3 there is little change from June to August and this period of minimum seasonal change is therefore favored when leaf samples cannot be taken simultaneously. The data further indicate that established differences in the leaf phosphate contents of two orchards continue to be reflected during this period of minimum change. Note that the high values in plot No. 5 appear throughout this entire period.

The leaf samples which were collected from the 130 orchards were taken in June and July and the agreement between the monthly averages for each variety suggests that, in general, the leaves were collected during this period of minimum seasonal change. The June and July averages for the designated varieties were found to be: Elberta, 0.19 and 0.17 per cent; Lovell, 0.22 and 0.18 per cent; Paloro, 0.19 and 0.17 per cent; Phillips, 0.20 and 0.18 per cent, respectively.

METHOD OF SAMPLING AND TREE VARIABILITY

Sampling in mature trees was generally limited to basal leaves on current growth. In case of young peach trees, where there may be as many as three cycles of growth in a single season, only the basal leaves on the first cycle were selected. A few comparisons indicate that large differences in phosphate may be found between leaves of varying age so that only leaves of the same type and age can be compared in attempting to establish the phosphorus levels in various orchards.

One hundred leaves seem ample and these are gathered by walking around the tree and removing one to two leaves from the base of a single shoot. By this method, repeated samplings on a single tree do not differ by more than $\pm .01$ per cent P.

There seem to be large differences in the leaf phosphorus content between individual adjacent trees, which continue to be evident throughout the season. This is particularly true in the plots where the phosphate is high. Thus when comparable data from individual trees are examined, 0.30 to 0.45 per cent P may represent the *range* of values found in a "high" orchard whereas 0.13 to 0.15 per cent P is characteristic of a "low" area. On the basis of averages of replicate samples, ten tree plots appear to give satisfactory agreement.

A comparison of the two seasons in Table II shows that there can be a definite seasonal variation. The 1941 data are approximately 20 per cent higher than the 1940 data. The set of fruit was much lighter in 1941 and this may have contributed to the difference.

EFFECT OF SOIL MOISTURE AND NITROGEN ON PHOSPHORUS CONTENT OF PEACH LEAVES

Although the 130 orchards included in the survey are all commercial orchards, there were and had been variations in nitrogen fertilizer and irrigation practices. Their influences on the phosphorus content of the leaf might affect the interpretation of such data.

An excellent opportunity to study the effects of nitrogen fertilization and soil moisture on the phosphorus in the peach leaf was afforded in the Phillips peach irrigation plots of Hendrickson and Veihmeyer (4). Each irrigation plot consists of three rows, the middle or experimental

row and two guard rows. In addition to the variable irrigation treatments, A (wet) and D (dry), described in (4), an application of 10 pounds per tree of ammonium sulphate had been added annually in 1939, 1940 and 1941 to the middle experimental rows, leaving the two guard rows in each irrigation plot without added nitrogen. Eight to ten trees were sampled individually in each treatment. There were five or six samplings from June to September in each season in 1940 and 1941. The summarized data from these experimental plots are given in Table II. In 1940, row 10, which had received four irrigations

TABLE II—THE PHOSPHORUS AND NITROGEN CONTENT OF PEACH LEAVES AS AFFECTED BY NITROGEN FERTILIZATION AND IRRIGATION (PHILLIPS CLING VARIETY, FIELD 7, UNIVERSITY FARM, DAVIS)

Row	Treatment	1940					1941					
		Jun 26	Jul 25	Aug 11	Aug 26	Sep 12	May 27	Jun 23	Jul 7	Jul 28	Aug 11	Sep 1
Phosphorus in Dry Leaf Matter (Per Cent)												
10	Irrigation	0.20	0.22	0.23	0.21	0.25	0.31	0.26	0.28	0.28	0.31	0.30
11	Irrigation + N	0.16	0.16	0.16	0.17	0.17	0.25	0.18	0.20	0.21	0.19	0.20
2	No irrigation + N	0.15	0.12	0.12	0.12	0.12	0.19	0.17	0.17	0.16	0.16	0.13
3	No irrigation	—	—	—	—	—	0.23	0.20	0.19	0.18	0.18	0.15
12	Irrigation	—	—	—	—	—	0.28	0.22	0.28	0.27	0.29	0.29
Nitrogen in Dry Leaf Matter (Per Cent)												
10	Irrigation	2.12	1.96	1.79	1.70	1.72	2.51	2.35	2.48	2.32	2.22	1.98
11	Irrigation + N	2.39	2.26	2.04	1.88	1.82	2.84	2.70	2.72	2.59	2.50	2.15
2	No irrigation + N	2.65	2.45	2.41	2.22	2.23	2.98	2.95	3.27	3.08	2.90	2.54
3	No irrigation	—	—	—	—	—	2.85	2.68	2.68	2.61	2.57	2.35
12	Irrigation	—	—	—	—	—	2.47	2.27	2.45	2.19	2.11	1.92

(treatment A) but no N, had the highest phosphate. Row 2, which had received N and no summer irrigation (treatment D), had the lowest phosphate, approximately half as much as row 10. Row 11, which had received four irrigations plus N had the intermediate phosphate content. The differences were large and consistent.

A suggested explanation to the above is the reciprocal relationship between N and P. Row 10 had the highest phosphate due to the frequent irrigations which probably tended to leach the nitrates and/or limit nitrification, resulting in the highest phosphate uptake. Row 2, with no summer irrigation and no leaching of either the added N or that already present earlier, had therefore the highest nitrate and the lowest phosphate uptake. With similar reasoning, row 11 would have an intermediate nitrate content and therefore an intermediate phosphate content.

Leaf analyses for nitrogen (Table II) confirmed these premises and the additional study in 1941 of the N and P relationship in row 3, no summer irrigation and no nitrogen, and row 12, frequent summer irrigation and no nitrogen (similar to row 10), added further confirmation.

The phosphate differences in the leaves from the various plots are not accounted for by any alteration in the percentage of dry matter. The green and dry weights per leaf were approximately equal in the five rows. This indicates that the lower phosphate in row 11 is not a

TABLE III—PEACH LEAF P (SURVEY 1940)

P in Dry Leaf Matter (Per Cent)		Orchard	Age	Tree Size	Foliage	Yields (Tons/Acre)	Soil Type*	County
Average	June	July						
0.260	0.30	0.22	19	Small	<i>Elberta Variety</i>	8	Holland s.l. (shallow)	Placer
0.250	0.26	0.24	19	Small		Low	Holland s.l. (very shallow)	Placer
0.250	0.24	0.20	22	Average		9	Fresno s.l. (brown)	San Joaquin
0.210	0.23	0.17	32	Average		2	Yolo silty c.l.	Solano
0.200	0.23	0.17	32	Average		6	Yolo silty c.l.	Solano
0.200	0.22	0.15	17	Average		18	Fresno s.l.	San Joaquin
0.195	0.24	0.18	25	Average		15	Capay silty c.l.	Solano
0.195	0.21	0.17	11	Large		6	Hanford f.s.l.	Kings
0.190	0.20	0.18	11	Average		8	Wyman c.l.	San Joaquin
0.190	0.20	0.17	17	Small		6	Arvin loamy f.s.	Kern
0.190	0.20	0.18	19	Average		14	Hanford f.s.l.	Kings
0.185	0.20	0.17	14	Small		14	Gravel l.	San Joaquin
0.185	0.20	0.17	16	Average		19	Gravel l.	Kern
0.185	0.19	0.18	14	Average		17	Gravel l.	Sutter
0.180	0.18	0.16	30	Average		9	Gravel l.	Fresno
0.180	0.20	0.16	8	Small		4	Gravel l.	Stanislaus
0.180	0.18	0.16	5	Small		11	Gravel l.	Stanislaus
0.180	0.18	0.17	16	Small		13	Gravel l.	Stanislaus
0.175	0.18	0.17	16	Large		17	Gravel l.	Stanislaus
0.175	0.16	0.19	20	Average		10	Gravel l.	Tulare
0.175	0.17	0.18	20	Small		7	Gravel l.	Tulare
0.170	0.18	0.16	7	Small		12	Gravel l.	Tulare
0.170	0.18	0.16	32	Average		9	Gravel l.	Tulare
0.170	0.18	0.16	35	Average		14	Gravel l.	Tulare
0.170	0.19	0.15	35	Average		5	Gravel l.	Tulare
0.170	0.19	0.15	7	Small		20	Gravel l.	Tulare
0.170	0.16	0.18	13	Average		8	Gravel l.	Tulare
0.165	0.17	0.16	18	Average		15	Gravel l.	Tulare
0.165	0.18	0.15	20	Large		18	Gravel l.	Tulare
0.160	0.16	0.16	22	Average		15	Gravel l.	Tulare
0.155	0.16	0.15	22	Small		12	Gravel l.	Tulare
0.155	0.16	0.15	5	Small		15	Gravel l.	Tulare
0.155	0.16	0.15	10	Average		13	Gravel l.	Tulare
0.150	0.17	0.13	7	Average		3	Gravel l.	Tulare
0.150	0.16	0.14	13	Average		7	Gravel l.	Tulare
0.150	0.16	0.14	4	Small		20	Gravel l.	Tulare
0.145	0.16	0.13	29	Small		11	Gravel l.	Tulare
0.145	0.16	0.13	12	Small		11	Gravel l.	Tulare
0.145	0.16	0.13	15	Large		11	Gravel l.	Tulare

Loell Variety

0.265	0.31	0.22	W. V. Smith	19	Large	Good	16	San Joaquin c.l.	Tulare
0.250	0.29	0.21	B. F. Dutcher	11	Large	Good	20	Hanford f.s.l.	Pesno
0.240	0.26	0.22	R. Swanson	12	Average	Good	14	Columbia f.s.l.	Kings
0.235	0.26	0.21	F. H. Weeks	18	Average	Fair	10	Wyman c.l.	Tehama
0.220	0.23	0.21	C. Chase	9	Average	Good	12	San Joaquin	San Joaquin
0.215	0.29	0.14	B. Oz	4	Large	Excellent	—	Fresno s.l. (brown)	Fresno
0.215	0.24	0.18	J. L. Johnson	10	Average	Excellent	10	Gridley l.	Butte
0.205	0.23	0.16	C. H. Vesser	17	Average	Fair	13	Pesno f.s.l.	Stanislaus
0.205	0.22	0.16	J. H. Beatty	34	Average	Good	13	Gridley-Fresno s.	Pesno
0.195	0.23	0.18	P. Beard	16	Average	Fair	15	Gridley f.s.l.	Stanislaus
0.195	0.21	0.18	A. H. Wheeler	28	Large	Good	13	Gridley f.s.l.	Stanislaus
0.190	0.22	0.17	Patterson Ranch	13	Average	Good	17	Yolo c.l.	Stanislaus
0.190	0.21	0.18	A. Metzler	28	Average	Good	11	Wyman silt l.	Stanislaus
0.190	0.21	0.17	El Solero Ranch	14	Average	Excellent	12	Yolo c.l.	Sofano
0.190	0.20	0.18	J. G. Sutton	25	Average	Excellent	15	Capay silty c.l.	Pesno
0.190	0.22	0.16	A. M. Morton	7	Small	Chlorotic	—	Fresno s.l.	San Joaquin
0.185	0.20	0.17	L. Strand	12	Average	Good	15	Chino f.s.l.	Tulare
0.180	0.21	0.15	D. M. Terry	18	Very large	Excellent	16	Yolo c.l.	Yolo
0.175	0.19	0.16	University Farm	18	Average	Good	30	Nadera s.	Merced
0.175	0.16	0.13	W. S. Batterman	14	Small	Good	14	Gridley f.s.l.	San Joaquin
0.175	0.16	0.13	N. Ames	18	Average	Good	12	Gridley f.s.l.	Butte
0.170	0.17	0.17	J. Palmer	5	Average	Excellent	—	Hesperia s.l.	Kern
0.170	0.18	0.16	C. Westenberg	20	Large	Excellent	4	Madera s.	Merced
0.165	0.19	0.14	M. C. Jenkins	5	Average	Excellent	18		

Paloro Variety

0.245	0.25	0.24	M. Serimian	13	Very small	Fair	3	Fresno s.l.	Fresno
0.230	0.24	0.22	C. H. Jones	16	Average	Fair	14	Fresno f.s.l.	Stanislaus
0.220	0.21	0.23	W. Vilen	17	Small	Poor	10	Fresno s.l.	San Joaquin
0.220	0.22	0.22	Woodbridge Fruit	16	Average	Excellent	10	Hanford s.l.	San Joaquin
0.215	0.21	0.22	O. K. Fink	8	Large	Good	20	Fresno s.l.	Kings
0.205	0.25	0.16	M. Orteson	—	Small	Poor	6	Fresno s.l.	Pesno
0.205	0.17	0.23	C. J. Davis	9	Average	Good	10	Fresno s.l.	Pesno
0.195	0.21	0.18	S. H. Dresser	12	Small	Fair	12	Fresno f.s.l.	Stanislaus
0.195	0.21	0.16	R. R. Ventrone	13	Large	Excellent	12	Hanford s.l.	Tulare
0.190	0.17	0.13	P. Arthur	13	Large	Good	7	Foster s.l.	Kings
0.185	0.19	0.18	W. B. Parker	13	Average	Fair	10	Wyman c.l.	San Joaquin
0.185	0.17	0.20	C. Lindauer	17	Average	Fair	6	Vina f.s.l.	Tehama
0.185	0.20	0.17	R. W. Miller	18	Large	Good	12	Hesperia s.l.	San Joaquin
0.185	0.21	0.16	E. S. Weller	17	Fair	Poor	3	Hesperia s.l.	Kern
0.180	0.18	0.18	Ord Ranch	14	Large	Excellent	12	Columbia silt l.	Butte
0.180	0.17	0.19	S. Hamamoto	15	Small	Good	Low	Holland silt l.	Placer
0.180	0.20	0.16	H. G. Littlejohn	20	Average	Good	20	Gridley s.l.	Sutter
0.180	0.16	0.16	H. H. Welsh	13	Large	Excellent	13	Fresno s.l.	Pesno
0.175	0.18	0.17	V. Bremer	16	Large	Good	13	Gridley l.	Sutter
0.175	0.17	0.17	V. Hoffman	17	Very large	Excellent	18	Hanford s.l.	San Joaquin
0.170	0.17	0.17	E. F. Eckhart	15	Average	Excellent	4	Holland s.l.	Placer
0.170	0.19	0.17	Patterson Ranch	13	Average	Fair	12	Yolo c.l.	Stanislaus
0.170	0.19	0.15	L. Hudson	13	Large	Excellent	15	Bear River s.l.	Sutter

*The soil type data have been taken from the Soil Surveys, Bureau of Chemistry and Soils, U. S. Department of Agriculture. The following abbreviations have been used: c—clay; f—fine; s—sand or sandy; l—loam.

TABLE III (Concluded)

P in Dry Leaf Matter (Per Cent)			Orchard	Age	Tree Size	Foliage	Yields (Tons/Acre)	Soil Type*	County
Average	June	July							
<i>Paloma Variety</i>									
0.165	0.16	0.17	A. Adrian	16	Large	Fair	13	Oakley-Fresno s.	San Joaquin
0.165	0.19	0.14	C. Wetmore	16	Large	Good	13	Peather silt l.	Yuba
0.165	0.17	0.16	El Solvo Ranch	17	Large	Excellent	15	Yolo c. l.	Stanislaus
0.180	0.18	0.14	C. K. Roddan	15	Large	Fair	12	Bear River s. l.	Yuba
0.160	0.16	0.16	C. B. Harris	15	Large	Excellent	10	Fresno s. l.	Fresno
0.150	0.16	0.14	F. Bentley	16	Large	Excellent	13	Bear River silt l.	Sutter
0.150	0.16	0.14	L. Martin	16	Average	Chlorotic	9	Boster f. s. l.	Tulare
0.150	0.16	0.14	A. K. Andross	13	Large	Good	—	Gridley c. l.	Sutter
0.150	0.16	0.14	P. Erickson	13	Average	Good	11	Feather l.	Yuba
0.150	0.17	0.13	E. J. Porter	12	Small	Fair	6	Madera s.	Merced
0.140	0.16	0.14	F. Porter	15	Average	Good	12	Gridley l.	Sutter
0.145	0.17	0.12	E. B. Wood	20	Small	Good	7	Madera s. l.	Merced
<i>Phillips Variety</i>									
0.320	0.48	0.16	Woodbridge Fruit	18	Average	Good	10	Hanford s. l.	San Joaquin
0.270	0.32	0.22	J. C. Randall	18	Average	Good	7	Exeter l.	Tulare
0.220	0.28	0.16	H. A. Struble	36	Average	Fair	3	Holland s. l.	Placer
0.250	0.24	0.26	R. L. Tudsbury	42	Snags	Poor	8	Holland s. l.	Placer
0.250	0.30	0.20	A. K. Andross	20	Small	Poor	10	Gridley l.	Sutter
0.215	0.26	0.17	J. G. Carlson	12	Average	Poor	3	Fresno s. l.	Fresno
0.200	0.21	0.21	D. Bache	20	Large	Excellent	15	Madera s.	Merced
0.190	0.17	0.19	W. B. Parker	13	Small	Fair	8	Wymann c. l.	San Joaquin
0.190	0.20	0.18	H. H. Welsh	12	Large	Good	12	Oakley-Fresno s.	Tulare
0.190	0.20	0.18	H. H. Anderson	21	Large	Excellent	10	Hanford s. l.	Stanislaus
0.190	0.16	0.22	C. H. Jones	17	Large	Fair	15	Fresno f. s. l.	Stanislaus
0.190	0.22	0.14	J. H. Hanna	15	Average	Excellent	15	Wymann c. l.	San Joaquin
0.180	0.22	0.14	S. C. Davis	13	Large	Excellent	15	Bear River silt l.	Sutter
0.180	0.20	0.16	J. P. Schafer	20	Large	Fair	10	Fresno s. l.	Fresno
0.175	0.17	0.18	P. Schafer	16	Average	Poor	8	Fresno s. l. (brown)	San Joaquin
0.170	0.16	0.18	A. H. Hughes	18	Large	Excellent	12	Gridley l.	Butte
0.170	0.16	0.18	G. H. Dresser	10	Average	Fair	10	Fresno f. s. l.	Stanislaus
0.165	0.15	0.16	H. Fillmore	17	Average	Fair	14	Yolo c. l.	Stanislaus
0.165	0.17	0.16	R. Kloppe	15	Small	Poor	15	Bear River silt l.	Sutter
0.160	0.16	0.16	F. Bentley	16	Large	Excellent	15	Oakley-Fresno s.	San Joaquin
0.160	0.16	0.16	H. Rollins	18	Large	Good	16	Oakley-Fresno s.	San Joaquin
0.160	0.16	0.16	University Farm	18	Large	Fair	5	Yolo c. l.	Yolo
0.160	0.16	0.17	V. Werners	16	Large	Good	15	Gridley l.	Sutter
0.155	0.15	0.17	P. Werners	16	Large	Excellent	16	Peather silt l.	Yuba
0.155	0.16	0.15	E. Solvo Ranch	17	Large	Excellent	11	Yolo c. l.	Stanislaus
0.150	0.15	0.15	Woodbridge Fruit	17	Very large	Good	18	Columbia f. s. l.	San Joaquin
0.150	0.15	0.15	O. K. Roddan	17	Average	Fair	12	Bear River silt l.	Yuba
0.140	0.15	0.13	C. P. C. Langedon	20	Average	Good	12	Madera s.	Merced

*The soil type data have been taken from the Soil Surveys, Bureau of Chemistry and Soils, U. S. Department of Agriculture. The following abbreviations have been used: c—clay; f—fine; s—sand or sandy; l—loam.

"dilution effect"; nor was the K content of the leaf influenced by the nitrogen in rows 10 and 11 (1). Nitrogen which under certain conditions (5) appears to influence the K content of the leaf of fruit trees has, under our conditions at Davis, had no effect on this cation although it has decreased the phosphorus. The reciprocal anionic effect therefore appears to be more related to the nitrate-phosphate composition of the soil solution than to any growth differences in the leaf. The average phosphorus in row 10, which received no nitrogen, was 37 and 39 per cent higher in 1940 and 1941 than the adjacent N treated row 11.

Still larger differences are produced by adding N and withholding summer irrigation. Thus row 10 is 74 and 82 per cent higher, respectively, in 1940 and 1941 than the non-irrigated N treated row 2. The conclusion drawn from these data is that peach orchards which have received heavy N fertilization and/or suffered from drought may be relatively low in phosphorus. These factors may be as important as the availability of phosphorus in the soil in determining the phosphorus content of the peach leaf. It should be noted that the drought conditions (treatment D) are probably more severe than would be found in good commercial peach orchards.

PRESENTATION OF SURVEY DATA

The phosphorus analyses of the leaves from the survey are listed in Table III. They have been arranged according to variety and in a descending order of their average June and July phosphorus content.

The Elberta data show that some of the best orchards have the lowest phosphorus. The Grant Merrill and Perry orchards are very excellent, yet they are the lowest in P. The excellent Serabian and Jenkins orchards also have low values. On the other hand, the Sill, Peterson, Bline and Vaughn orchards, all located in Tehama County, have not made good growth and are also low in phosphorus. There is also a tendency for some of the poorer growing orchards to have a *high* phosphorus content. This may be noted in the two Penryn Fruit Company orchards and in the Fitzpatrick orchard. Experimental data are not available to account for these differences in the poorer growing Elberta orchards. Trials with additional irrigation and others with phosphate applications on the "low" poorer growing orchards in Tehama County would be of interest in this connection.

In the Lovell variety the number of orchards studied are fewer and there are not as marked variations in growth between orchards. In general those making the greater growth have the lower phosphorus. The Jenkins and Batterman trees are outstandingly vigorous and are in the lower phosphorus group. The Dutcher, Swanson and Weeks orchards are not making as satisfactory growth and appear to have higher phosphorus. The older Palhorn orchard shows less vigor than the younger and has a higher phosphorus content. The Lovell data are in agreement with the Elberta in that the better orchards are relatively the lowest in phosphorus.

The Paloro data again suggest that trees making little growth may be high in phosphorus. The Serimian orchard had made the poorest

growth of any and is the highest in the Paloro group. One might have expected it to be the highest in the entire survey since these trees appeared to have made the smallest growth. The better Paloro orchards, Hoffman, Hudson, Bremer, Wetmore and Mehrton, do not have the lowest phosphorus values. No explanation can be offered at this time for this inconsistency.

The Phillips analyses are, however, in accord with the general finding that the orchards with the least growth are higher in phosphorus in the leaf than are the vigorous growing trees. In the Phillips data, the high Woodbridge, Randell, Struble, Tudsbury, Andross and Carlson orchards made appreciably less growth in 1940 than did the low Woodbridge, El Solyo, Wetmore and Bremer orchards.

In general, the poor orchards in the survey did not exhibit a low phosphorus content of the leaf, suggesting that the lack of growth was not due to any dearth of this element in California orchards. Conversely, the lower phosphate in the leaf could most frequently be associated with the better orchards and the minimum values reported in these data cannot be considered likely to be in the deficiency range.

The average of the June and July phosphorus values for the 130 orchards was 0.185 per cent P. The range was from 0.140 to 0.270 per cent P and the mode, the percentage of greatest frequency, was found to be 0.185 per cent. It is of particular importance to note that the magnitude of difference which exists between the highest and lowest orchard can also be found to exist between rows in the same orchard which differ only in the amount of N and irrigation water they receive.

The reciprocal relationship between N and P has been frequently reported (6) but its significance in any attempt to use leaf analyses as a criterion of phosphate needs of California peach orchards was not determined until these data became available. It now appears as if the P content of the peach leaf in California may often be a better measure of the tree's need for nitrogen than for phosphorus. Leaf analyses thus far do not appear to be so favorable criteria for phosphorus needs as for potassium needs.

It is difficult to find any reference to phosphate responses in which leaf analyses are included, particularly in the case of bearing peach trees. Cullinan, *et al.* (7) find a decreased growth of young peach trees growing in nutrient solution when the value in October was 0.11 per cent P or less in the leaf. In a nutrient solution which contained abundant phosphate (93 parts per million) they were able, by varying the nitrogen supply, to vary the P content from 0.41 to 1.78 per cent. While this range of values exceeds that reported in this survey they are of interest in that they show the inverse growth relationship which was also evident in our field data. Their trees having 0.41 per cent leaf phosphorus weighed 615.2 grams while those having 1.78 per cent P weighed from 70 to 90 grams.

We have reported (2) increased growth of Elberta peach trees when the phosphate was placed in the hole at planting time where the phosphate content in the unfertilized leaf was 0.11 per cent. The response appears to be partly due to transplanting. The addition of phosphate

to fruit trees 1 to 3 years after planting failed to give response in this same soil.

Some excellent orchards in the survey had July values which approached the threshold value (0.11 per cent) reported by Cullinan. In the Elberta group the Grant Merrill (.13 per cent P), Perry (.13 per cent P); in the Lovells, the Westenberg (.14 per cent P) and Jenkins (.14 per cent P); in the Paloros, the Wood (.12 per cent P), Bentley (.14 per cent P) and Wetmore (.14 per cent P); and in the Phillips the Hudson (.14 per cent P) orchards all must be considered very good California peach orchards.

COMPARISON OF SURVEY DATA AND LEAF ANALYSES FROM THE LOW PHOSPHORUS AIKEN SOIL.

When the leaf analyses obtained in the survey and those from the Elberta trees planted in 1934 in our experimental plots on the low phosphate soil at Paradise are compared, it appears that the experimental trees which have received an increasing amount of N since planting (1941, 10 pounds $(\text{NH}_4)_2\text{SO}_4$) are as low as any of those in the survey. A greater difference might have been expected on a soil as low in phosphorus as this one. During certain seasons, these trees have had (see Table I, Plot 1) a leaf phosphorus content as low as 0.11 per cent P, which corresponds to the limiting value suggested by the data of Cullinan, *et al.* (7). This is lower than any reported in the 1940 survey. The trees have yielded 11 tons per acre in their fourth leaf and continued to increase to an 18-ton production in their sixth leaf. This is an excellent yield record. The fruit was of high quality. If these experimental trees on the Aiken soil continue to bear well without the addition of phosphate then it appears that the application of this element to other orchards in California may not be a profitable practice.

The marked response of annual crops on the Aiken soil, reported elsewhere (3), should be noted. When one considers the extreme unavailability of the phosphorus on this particular soil as measured by other crop plant growth in the field and by chemical and biological tests in the laboratory, then the ability of peach trees in this same soil not only to reflect in their leaf analyses a probable sufficiency of phosphorus but to grow and bear well is a contrast of major import to phosphorus fertilizer recommendations. Neither responses of annual crops to phosphate nor leaf analyses appear to be good criteria for determining the phosphate needs of fruit trees in California.

SUMMARY

The percentage of phosphorus in the dry matter of the peach leaf decreases rapidly during spring and early summer. This early seasonal decline is followed by a period of minimum seasonal change which continues until the leaves yellow in the fall. Comparisons of the phosphorus content of various peach orchards were limited to leaf samples taken during mid-summer.

Variations in the P content of the leaf were found between adjacent peach trees and a greater variability was associated with the trees

having the higher analyses. The averages of 10 trees showed satisfactory agreement.

The phosphate content of the leaf varied markedly with nitrogen fertilization and irrigation. The magnitude of the difference produced by these two factors in a single orchard corresponded to the difference found between the "high" and "low" analyses in a survey of 130 peach orchards.

The average per cent P in the dry matter of the leaf in 130 California peach orchards was .185 and the range was from 0.14 per cent to 0.27 per cent P. Poor growth could frequently be associated with "high phosphorus". Conversely, many of the best orchards had a "low phosphorus" content.

Peach trees which are making good growth on a soil that is very low in available phosphorus have a phosphorus leaf content which approximated that found in many of the best orchards on the more fertile soils included in the survey.

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A Preliminary Study of the Manganese Content of the Leaves of Some Deciduous Fruit Trees

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IN a recent survey and leaf sampling of peach orchards, Lilleland (1) had noted that several of the orchards were affected with a chlorosis which had not been diagnosed although it had been present in these orchards for many years. The condition was general over the whole tree and gave an unhealthy appearance to the entire orchard. A few orchards were also found in which the chlorotic condition appeared in a much milder degree and these might have escaped notice except for the closer inspection associated with leaf sampling. These original field observations interested us to make the studies described in this paper.

In the spring of 1941 a branch on each of 10 trees in the severely chlorotic Roberts orchard near Suisun was sprayed with 1 per cent MnSO_4 solution and 2 weeks later it was evident that this chlorotic condition was due to a manganese deficiency. The foliage on the sprayed branch was normal in color while the rest of the tree remained chlorotic.

Mn deficiency in the field produces a rather distinct leaf pattern with many deciduous fruit trees (Fig. 1). The midrib and main veins

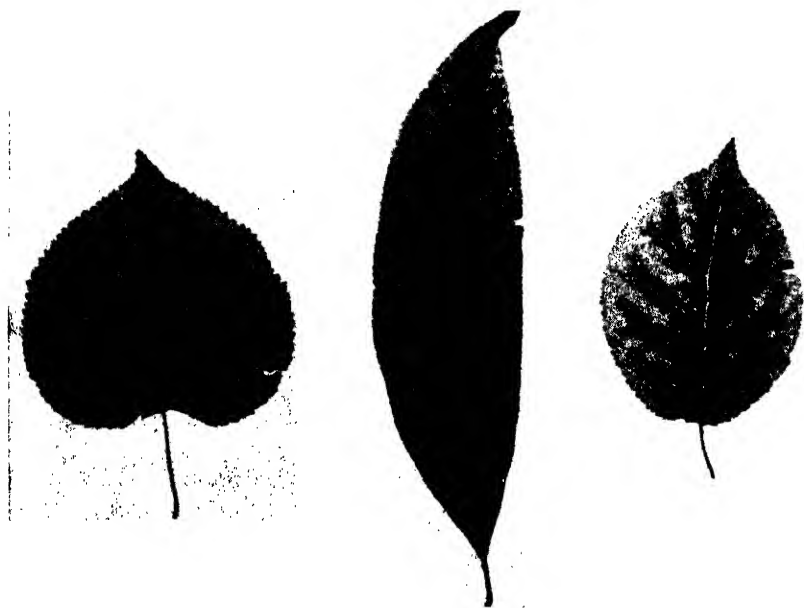


FIG. 1. Manganese deficiency symptoms in apricot (left), peach (center) and plum (right). Note the wide banding of green tissue adjacent to the midrib and larger veins, which is a typical pattern associated with Mn deficiency in many deciduous fruit tree species.

with adjacent bands of tissue of varying width remain green whereas the interveinal and peripheral areas are chlorotic. As noted earlier, this condition may be general throughout the entire tree but in mild cases it may be limited to only a few small branches. Very severe Mn deficiency symptoms of walnut trees in California have been described by Braucher and Southwick (3). Having ascertained that the chlorosis was due to manganese, we became interested in knowing what the concentrations might be in healthy and chlorotic peach leaves and how these might vary throughout the season. We extended the study to other species of fruit trees when manganese chlorosis was later detected with some of them. In addition we have made leaf analyses on Mn treated and chlorotic (check) trees, some from our own experimental trials and others from field experiments conducted by county agents. Determinations of pH and total manganese of some of the soils were also made.

METHODS AND MATERIALS

All samples represent 100 mature basal leaves on current growth. In the survey of 30 Elberta peach orchards (Table I) 10 such leaves were selected from each of 10 trees. For the determination of the leaf Mn content of the different species and of seasonal changes of the Mn content, 3 to 12 samples representing individual trees were analyzed and averaged. The periodate method as described by Willard and Greathouse (4) was used and the concentration of the permanganate solution was determined with a Klett colorimeter. Results are expressed in parts per million Mn on a dry leaf matter basis.

THE ELBERTA SURVEY

Leaf samples which had been taken in June and again in July 1940 from 39 Elberta orchards were analyzed for Mn. The Mn analyses together with certain orchard data are presented in Table I. They have been arranged in a descending order of the average June and July Mn contents. These values ranged from 293 parts per million to 6 parts per million.

Distinct leaf symptoms were noted in the Syll, Murray and Roberts orchards at sampling time and mild symptoms were evident in the Sutton orchard later in November. These four orchards had an average June and July leaf analysis of less than 17 parts per million Mn in the dry leaf matter. Despite the leaf symptoms and low analyses the growth and yields were not always reduced appreciably. The Roberts orchard was the most severely affected and it seemed likely that the Mn deficiency here had reduced the crop. With normal foliage their bearing area should have produced a probable 10 ton yield in contrast to the actual 3 tons harvested. The Sutton orchard, however, was a very good orchard with excellent yields and it was fairly typical of orchards with mild leaf symptoms. A tolerance to a low manganese is also suggested by the past growth made by these orchards. The large size of their trunk and scaffold branches is indicative of this and their age (Table I) is further attest. The Roberts orchard is reported to have shown no symptoms during the first 15 years after planting. How-

TABLE I—THE MN CONTENT OF PEACH LEAVES FROM 39 ELBERTA ORCHARDS IN CALIFORNIA

Mn in Dry Leaf Matter (Ppm)			Age	Tree Size	Foliage	Yields Tons Acre	Soil Type*	County
Average	June	July						
293.2	261.7	324.6	20	Large	Very excellent	18	Madera s.	Merced
237.2	196.2	278.2	32	Average	Good	12	Madera s.	Merced
113.2	70.2	156.2	22	Average	Fair	9	Presno s.l. (brown)	San Joaquin
93.2	93.1	93.1	19	Small	Good	—	Holland s.l. (very shallow)	Placer
78.0	56.8	99.2	17	Small	Good	6	Arvin loamy f.s.	Kern
71.1	64.8	77.3	5	Small	Very excellent	—	Arvin loamy f.s.	Stanislaus
65.9	56.7	75.0	19	Small	Good	8	Holland s.l. (shallow)	Placer
60.6	59.0	62.2	12	Average	Good	20	Holland s.l. (shallow)	Tehama
56.4	53.5	59.3	13	Average	Very excellent	20	Fresno s.l.	Stanislaus
54.1	50.4	57.8	8	Small	Good	9	Fresno s.l.	Tehama
53.5	49.0	57.9	7	Small	Poor	5	Tehama silt l.	Stanislaus
49.7	42.5	56.8	6	Small	Fair	4	Madera s.l.	Presno
48.6	24.2	56.8	20	Small	Fair	10	Madera s.l.	Presno
45.2	38.0	52.3	30	Average	Good	7	Oakley Fresno s.	Presno
43.4	42.2	44.6	22	Average	Excellent	15	Fresno s.l.	Presno
42.7	40.0	45.3	5	Large	Good	12	Gridley l.	Butte
42.1	33.1	51.0	20	Average	Very excellent	13	Yolo c.l.	Stanislaus
41.7	38.1	45.3	18	Average	Fair	18	Fresno s.l.	San Joaquin
41.5	38.8	44.2	17	Small	Good	3	Maywood l.	Stanislaus
40.4	29.7	51.0	35	Average	Good	9	Greenfield s.l.	Tulare
39.1	41.4	36.8	35	Average	Excellent	14	Madera s.l.	Presno
37.5	28.6	40.3	14	Small	Good	13	Hanford s.l.	San Joaquin
34.7	29.9	39.4	13	Average	Good	—	Hanford s.l.	Kern
33.2	29.8	36.6	4	Small	Good	6	Arvin loamy f.s.	Kern
33.1	18.4	47.7	14	Large	Chlorotic	10	Traver l.	Kings
32.6	23.3	41.8	16	Average	Good	14	Gridley l.	Sutter
32.2	23.3	41.0	14	Average	Good	17	Hanford f.s.l.	Tehama
31.2	29.9	32.4	7	Average	Good	8	Columbia f.s.l.	Tulare
30.6	28.2	33.0	18	Large	Excellent	11	Chino f.s.l.	Kings
29.6	28.0	31.1	15	Large	Very excellent	5	Yolo silt c.l.	Tehama
26.5	20.1	32.8	19	Small	Slightly chlorotic	15	Vina l. (shallow)	Stanislaus
26.4	21.2	31.6	20	Average	Excellent	8	Yolo silt c.l.	Stanislaus
23.4	19.6	27.2	11	Average	Good	11	Wyman c.l.	San Joaquin
21.1	22.6	19.5	16	Large	Poor	17	Foster s.l.	Kings
18.5	17.7	19.2	25	Average	Excellent	15	Capay silty c.l.	Solano
16.7	14.0	19.3	29	Small	Chlorotic	7	Elder silt l.	Tehama
12.5	10.0	15.0	17	Average	Slightly chlorotic	6	Yolo silty c.l.	Solano
9.7	7.7	11.6	33	Average	Chlorotic	2	Yolo silty c.l.	Solano
5.6	5.5	5.6	33	Average	Chlorotic	2	Yolo silty c.l.	Solano

*The soil type data have been taken from the Soil Surveys, Bureau of Chemistry and Soils, U.S.D.A. The following abbreviations have been used: c—clay; f—fine; s—sand or sandy; l—loam.

ever, a young 10-year-old orchard adjacent to these old trees is already showing distinct Mn chlorosis.

The data from the other orchards in Table I give evidence that luxury consumption of Mn can be very great in the Elberta peach trees. The highest are about 20 times as much as in the lowest healthy orchard. The two highest values come from orchards located on a light soil, the Madera sand, while the Mn deficient orchards listed in Table I are located on relatively heavy textured soils mainly in Solano County.

The K and P analyses of these leaves are reported elsewhere (1, 2). There does not appear to be any correlation of these to the Mn content.

THE SEASONAL CYCLE

The data in Table I indicate a higher Mn concentration in peach leaves in July than in June. The time of sampling may therefore be important in making comparisons, particularly in the critical range and the seasonal changes in the Mn content of the peach leaf were therefore studied in six plots representing five peach varieties and two soil types. The orchards at Paradise, California, are on Aiken clay loam and those at Davis are on Yolo clay loam. The data which are reported in Table II show that there was comparatively little change in the percentage of manganese in the peach leaf from June to October. Several seasons are included.

The survey data suggest somewhat greater increases than does the June-July data in Table II. The mean average increase in the former is about 50 per cent and the most frequent increase (the mode) approximates a value of 15 per cent. A wider sampling on other soil types throughout the season would be desirable. The manganese content from the very deficient Roberts orchard showed a steady decline from 13 parts per million in June to 7 parts per million in September. It

TABLE II—SEASONAL CONTENTS OF MN IN THE PEACH LEAF
(PARTS PER MILLION MN IN DRY LEAF MATTER)

Description	May	Jun	Jul	Aug	Sep	Oct
J. H. Hale, Paradise 1932	45	44	47	42	46	46
J. H. Hale, Paradise 1933	43	41	41	46	46	—
Elberta, Paradise 1935	—	68	75	81	82	90
Phillips Cing. Davis 1940	—	17	23	22	16	—
Muir, Davis 1940	—	46	46	50	38	—
Lovell, Davis 1940	—	27	35	33	27	—
Elberta, Suisun 1941	—	13	9	—	7	—

appears that samples taken at any time from June to October will reflect the general level of Mn in the leaf. When values border on the limits of sufficiency (15 to 20 parts per million) and greater accuracy and confirmation are desirable a time series of samples throughout the summer should be helpful in making a more definite diagnosis. This is particularly indicated in the survey data in Table I in the Jenkinson orchard. The Mn content in June was 18 parts per million suggesting that the chlorosis, although not typical, might be a Mn deficiency. The higher content (47 parts per million) in July indicated that the condition was due to other factors.

COMPARISON OF THE MANGANESE CONTENTS OF VARIOUS FRUIT TREE SPECIES

In addition to our own observations various members of the Experiment Station staff have noted symptoms on other fruit tree species so that to date we have recognized Mn deficiency in apple, apricot, cherry, peach, plum and walnut. However, the acreage affected is very small. In some instances one species has shown symptoms while another in an adjacent row has normal foliage. Thus prune trees adjacent to the chlorotic peaches in Roberts orchard cited in Table I did not show any leaf symptoms. We therefore became interested in studying the leaf Mn content in the various species when grown under similar soil and climatic conditions. An experimental planting at Paradise, California, in which eight species of fruit trees are planted in eight parallel rows and from which leaf samples have been taken for several years, furnished suitable material for such a study. The soil is Aiken clay loam with a pH of 6. The following species were analyzed: filbert, *Corylus avellana*, var. Barcelona; English walnut, *Juglans regia*, var. Franquette; apple, *Malus sylvestris*, var. Red Delicious; pear, *Pyrus communis*, var. Old Home; peach, *Amygdalus persica*, var. Elberta; almond, *Amygdalus communis*, var. Nonpareil; European plum, *Prunus domestica*, var. Agen; and cherry, *P. avium*, var. Bing.

The data in Table III are from individual trees. The samples were taken in July. The averages range from 4.04 parts per million in the

TABLE III—A COMPARISON OF THE MN CONTENT OF EIGHT SPECIES WHEN GROWN IN THE SAME ORCHARD AND VARIATIONS IN THE LEAF CONTENT OF INDIVIDUAL TREES (AIKEN CLAY LOAM, PARADISE, CALIFORNIA)

Tree No.	Mn in Dry Leaf Matter (Ppm)							
	Row 1 Filbert	Row 2 Walnut	Row 3 Apple	Row 4 Pear	Row 5 Peach	Row 6 Almond	Row 7 Prune	Row 8 Cherry
16	357.1	271.2	124.6	80.7	64.0	93.7	67.3	—
17	645.2	—	80.5	53.6	63.2	—	55.3	64.5
18	714.3	257.4	60.2	44.6	58.9	71.7	90.1	—
19	456.3	—	89.7	86.3	62.1	127.1	81.6	71.7
21	—	—	75.7	54.6	81.0	93.9	76.3	—
22	—	250.0	86.3	96.2	71.8	92.6	69.0	—
23	—	—	74.0	77.6	79.0	89.7	82.4	—
24	—	213.6	54.9	59.0	57.1	101.5	69.8	—
26	362.5	211.1	79.7	51.1	66.3	102.5	58.6	58.9
27	444.5	—	110.0	55.9	71.9	71.1	92.6	53.9
28	466.9	271.2	68.7	66.8	58.3	110.7	69.3	60.5
29	504.8	—	89.1	32.1	59.3	—	61.2	69.1
Average	494.0	245.8	81.1	63.2	66.1	95.6	72.8	62.7
P. E. M.	±30.18	±7.47	±4.02	±3.62	±1.58	±3.57	±2.34	±1.73

filbert to 63 parts per million in the cherry. Next highest to the filbert is the walnut and then almond, while apple, prune, peach and pear occupy intermediate positions. The data do not suggest any marked ability of the Agen prune to absorb greater quantities than the Elberta peach in this particular soil. A subsequent comparison of prune and peach leaf analyses from the Roberts orchard confirms this. The high composition of the walnut leaves is of interest since instances of Mn deficiency with this species in California are relatively numerous and the symptoms may be quite severe (3).

In general the differences found between the following species — apple, pear, peach, prune and cherry — growing in the same orchard are not nearly as great as the differences found in a single species (Elberta peach) growing in different orchards (see Table 1).

The data in Table III also show that tree variability within a species may be high and suggest that attention should be given to this source of possible error when samples are taken for Mn analyses.

The leaves reported in Table III were entirely free of any manganese deficiency symptoms. The following analyses are from various fruit species in which Mn chlorosis indicated a deficiency. The samples were taken by various observers from basal leaves on current growth but were not collected at the same time of year. Apple (1 sample), 5 parts per million; apricot (3 samples), 9 to 14 parts per million; cherry (1 sample), 21 parts per million; peach (11 samples), 7 to 16 parts per million; prune (1 sample), 15 parts per million; and walnut (17 samples), 6 to 25 parts per million.

Although the data in Table III suggest some differences between species in the Mn contents of normal trees, the analyses of chlorotic foliage give general evidence that the critical concentration is about the same for all. This is particularly interesting in the case of the walnut since it had a distinctly high concentration in the species comparison of healthy trees listed in Table III.

COMPARISONS OF THE MN CONTENT OF CHLOROTIC AND CURED TREES

We have found that Mn chlorosis can be readily corrected on apricot and peaches by spraying the foliage with a 1 per cent MnSO_4 solution. In confirming a diagnosis we have used a small fly sprayer for spot treatments. In our field trials we have used a commercial orchard spray rig. The leaves from the sprayed trees were carefully washed before they were analyzed.

The analyses of sprayed foliage showed a high Mn content. In the Roberts orchard sprayed in May with 1 per cent MnSO_4 the Mn content was 400 parts per million in June compared to 12 parts per million in the check trees. This decreased during the season to 120 parts per million in October, while the chlorotic trees had 7 parts per million. Mr. Clark Swanson of the Extension Service injected 8,000 cubic centimeters of a 1 per cent MnSO_4 solution into a 10-year-old peach tree in September 1940 and in June 1941 he found 84 parts per million Mn in the leaves compared to 10 parts per million in the untreated tree. He also placed 2 grams of MnSO_4 in each of four holes in the trunk in February 1941 and found 142 parts per million Mn in the leaf compared to 8 parts per million in the untreated tree. Manganese absorption by the peach tree is therefore readily detected by chemical analysis and the concentrations obtained by various methods of application easily exceed the minimum associated with healthy peach foliage. The trees in the above cases all showed a clear response to the Mn treatments.

SOIL ANALYSES

Many investigators (5) working with annual crops have frequently correlated Mn deficiency with the pH of the soil. We were not able to establish with fruit trees any correlation between soil pH and Mn deficiency. We compared both surface (1st foot) and subsoil (3rd foot) samples using a glass electrode. The pH values were obtained on all 39 orchards listed in Table I and ranged from 6.3 to 8.1 in the first foot and 6.0 to 8.6 in the third foot of soil. All the determinations were made by adding enough water to the air dried soil to make a mud into which the electrode could be easily inserted.

We also studied the total Mn content in the soil in the four highest and four lowest orchards listed in Table I. Surface and subsoil samples were analyzed separately using the methods described in (6). However, no correlation could be noted between the total Mn content in the soil and that in the leaf. In fact the four deficient orchards were higher in every case than the four soils in which peach trees showed the highest leaf analyses. The values ranged from 500 to 1000 parts per million Mn.

Further attempts to differentiate these 8 soils by the Neubauer rye seedling method failed. The amounts of Mn extracted by the 100 rye seedlings from 100 grams of soil were small (0.4 milligram) and there were no differences which could be correlated with the leaf analyses.

SUMMARY

A chlorosis of peach leaves was found and identified as a manganese deficiency. Similar symptoms have subsequently been found on other species of fruit trees. Analyses of peach leaves from 39 Elberta orchards in June and July showed values ranging from 293 parts per million to 6 parts per million Mn on a dry weight basis. Deficiency symptoms in peaches could generally be associated with a Mn content less than 17 parts per million. A high luxury consumption of Mn is therefore indicated in some peach orchards. Tree growth and fruit yields did not appear to be appreciably reduced by the deficiency; fruit size was normal.

The changes in the Mn content throughout the summer were not large and it was concluded that samples taken from June to October will reflect the general level of Mn in peach trees. A study of eight species growing normally in the same soil showed that in July, filberts had 494 parts per million Mn; walnuts, 246; almonds, 96; apple, 81; prune, 73; peach, 66; pear, 63; and cherry, 63. Analyses of chlorotic leaves of six species from various soils gave values ranging from 5 to 25 parts per million Mn and seemed to show no differences which could be correlated with the species.

Foliage sprays, injection of Mn solutions into the branches, and placing Mn salts in holes in the trunk all were effective in increasing the Mn content in the leaf and curing the chlorotic condition. Neither the pH nor the total manganese content of the soil could be correlated with the manganese content of the peach leaf.

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Statistical Analyses of the Fertilizer Data From the Von Osten Apple Orchard¹

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THE sources of data for these studies have been the records from the fertilizer plots of the Von Osten apple orchard in the Wenatchee District of the State of Washington. The earlier records from these plots have been utilized as the basis for a previous publication (1). The treatments consisted of check (no fertilizer), N, P, K, NP, NK, PK, and NPK. There was one plot to each treatment, with three record trees per plot. There were thus four plots receiving nitrogen and four comparable plots not receiving nitrogen. The same balance held true with respect to phosphate and potash.

A careful examination has been made of the records obtained since the time of the previous publication, (1932 to 1935, inclusive) with regard to the following factors: (a) annual average total number of mature fruits produced per tree; (b) annual average total weight of matured fruit produced per tree; (c) annual average weight of individual apples; (d) annual average weight of extra fancy and fancy fruit produced per tree; (e) annual average percentage of total red color of the apples harvested from each plot; (f) the annual average terminal length growth; and (g) the annual average increase in trunk circumference per tree.

The reasons for using the years, 1932 to 1935, for the correlation studies and analyses of variance are as follows: (a) the data previous to this time have been published; (b) it was believed that records obtained near the close of the experiment would be more indicative of the influence of the fertilizers, than those obtained earlier, for the reason that the treatments would have had more time to become effective; (c) since 1935, nitrogen was applied to some of the plots not previously receiving nitrogen, because of the insistence of the co-operating grower; and (d) it was believed that the 4-year period would be sufficiently long to smooth out seasonal irregularities and any tendency toward biennial bearing.

METHOD OF ANALYSIS OF DATA

In view of the fact that there was only one plot per treatment, the only measure of error available by the usual procedure (2) would have been the interaction between treatments. This could have been considered valid only on the assumption that the interaction itself could be attributed primarily to "error". An examination of the data indicated that such an assumption could not safely be made. The procedure finally used for each type of record was as follows: (a) The variance due to the differences among trees within plots was determined. (b) From this was calculated the standard error of the differ-

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ence between two groups of 12 trees each, that is, four plots of three trees in each group. The procedure of Snedecor (2) was used for this calculation. (c) Multiplying this standard error by the "t" values for $P = .05$ and $P = .01$ gave the actual group differences for each type of record that were required for odds of 19:1 and for odds of 99:1. (d) The figures thus obtained were used for determining the significance of the difference between the mean of the four plots receiving nitrogen and the mean of the four not receiving nitrogen. The effects of phosphate and potash were determined in the same manner. The interactions were not considered reliable enough for presentation.

EFFECT ON TERMINAL GROWTH

The effects of the three elements, N, P, and K, on the length of terminal growth during 1932 and 1935 inclusive, are shown in Table I.

TABLE I—AVERAGE TERMINAL GROWTH (INCHES)

+N	-N	+P	-P	+K	-K
6.90xx*	4.15	5.45	5.60	4.90	6.15xx

*xx Indicates difference highly significant (odds greater than 99:1).

The nitrogen applications definitely increased the length of terminal growth, the length being over 50 per cent greater on the trees receiving nitrogen than on trees receiving no nitrogen. The statistical analysis showed this to be highly significant. The terminal growth was not affected by the application of phosphorus.

The potassium applications, however, actually decreased the terminal growth. There was a highly significant difference in this case.

EFFECT ON TRUNK CIRCUMFERENCE

An analysis of the data presented in Table II indicates that nitrogen is the only element that had a significant effect on the yearly increase in circumference.

TABLE II—AVERAGE ANNUAL INCREASE IN TRUNK CIRCUMFERENCE (CENTIMETERS)

+N	-N	+P	-P	+K	-K
2.1x*	1.1	1.7	1.5	1.4	1.8

*x Indicates difference significant (odds between 19:1 and 99:1).

The nitrogen approximately doubled the annual increase in trunk circumference. The phosphorus applications did not influence the increase in trunk circumference. It should be noted that there was a smaller increase in trunk circumference with trees receiving potash as compared with trees not receiving potash. This difference, while it was not significant, is in agreement with the data in Table I, that is, the application of potash actually had a depressing effect on the growth.

EFFECT ON AVERAGE NUMBER OF FRUITS

The trees that had received nitrogen in the fertilizer program produced a greater number of fruits per tree than did trees, which had not received nitrogen, the increase being highly significant. Neither of the other two elements significantly affected the average number of fruits borne per tree (Table III).

TABLE III—THE AVERAGE NUMBER OF FRUITS PER TREE

+N	-N	+P	-P	+K	-K
2161xx	1079	1533	1707	1632	1608

EFFECT ON ANNUAL WEIGHT OF FRUITS PRODUCED PER TREE

As with the total number of fruits borne per tree, there was about twice the weight of fruit borne on the trees that received nitrogen as was produced on trees receiving no nitrogen (Table IV).

TABLE IV—AVERAGE ANNUAL WEIGHT OF HARVESTED FRUITS PER TREE (POUNDS)

+N	-N	+P	-P	+K	-K
590xx	280	403	468	433	427

No significant differences were found between the other comparisons.

EFFECT ON AVERAGE WEIGHT OF INDIVIDUAL FRUITS

The analysis of the data summarized in Table V indicates that the size of individual fruits was not significantly increased or decreased by the applications of N, P or K.

TABLE V—AVERAGE WEIGHT OF INDIVIDUAL FRUITS (POUNDS)

+N	-N	+P	-P	+K	-K
.273	.260	.263	.274	.265	.275

The data in Tables III to V indicate that the effect of nitrogen in increasing yield largely resulted from the increased growth and the production of a greater number of fruits rather than as a result of increased size of individual fruits.

The reduction in growth on the plots receiving K, as compared with plots which did not receive K, did not have a corresponding effect on production of fruit. Since the size of the trunk in all plots was approximately the same, it can be concluded that the increase in crop on the plots receiving nitrogen did not result from a greater size of tree.

THE EFFECT ON AVERAGE PER CENT OF RED COLOR

The fruit borne on the trees that had received no nitrogen had considerably more red color than the fruits from the trees which had received nitrogen alone, with phosphorus, or potassium, or in combination with both (Table VI).

TABLE VI—THE AVERAGE PER CENT OF RED COLOR

+N	-N	+P	-P	+K	-K
55.3	74.7xx	64.4	59.1	63.4	59.8

The application of K or P had no significant effect on the color of the fruit.

EFFECT ON ANNUAL PRODUCTION OF FANCY AND EXTRA FANCY FRUITS

As with the per cent of red color the application of K or P did not significantly affect the annual production of fancy and extra fancy fruits (Table VII).

TABLE VII—AVERAGE ANNUAL PRODUCTION OF FANCY AND EXTRA FANCY FRUITS (POUNDS)

+N	-N	+P	-P	+K	-K
399x	234	307	326	322	310

Whereas the total per cent of red color of individual fruits was significantly decreased by the application of nitrogen alone or in combination with phosphorus or potassium or both, the nitrogen treated trees produced a significantly larger amount of fancy and extra fancy fruit. This apparently resulted from the fact that the N treated trees produced larger crops. Thus, the decrease in color was more than compensated for by the increase in yield, insofar as the total production of "Extra Fancy" and "Fancy" apples was concerned.

CONCLUSIONS

Tree growth, as measured by increase in trunk circumference and increase in terminal growth, was not affected by the application of phosphorus. Nitrogen applications significantly increased tree growth, whereas applications of potash actually decreased tree growth.

Tree yield was significantly increased only with the applications of nitrogen. The increase in yield from the application of this element was largely obtained from the increase in number of fruits rather than from an increase in size of individual fruits.

The red color of fruit was not affected by applications of P and K. Applications of nitrogen alone or with phosphorus or potassium or both decreased the red color of individual fruits. This, however, was more than compensated for in increased production, and the yield of extra fancy and fancy fruit was significantly increased by the application of fertilizer supplying this element.

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Adjustment of Yields in an Experiment with Orange Trees¹

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THE magnitude and nature of the errors involved in experiments with fruit trees have been emphasized by many investigators, including Batchelor and Reed (3) and Hoblyn (9). Because of the relatively large areas of land which must be used, the small number of trees involved, and the individuality and long life of the trees themselves, errors in such experiments are usually larger than those in agronomic trials. In recent years increased precision has resulted from the serious attempts of horticulturists to reduce the variability of the plant material used in their experiments. Moreover, the development of improved statistical techniques has permitted a better understanding and evaluation of the errors of field experiments and has greatly influenced the design and interpretation of the more recent orchard trials.

Some of the newly available techniques undoubtedly offer greater possibilities for improvement in experimental methods than has been generally realized. This appears to be true of the method of covariance. This valuable technique (6, 7, 10, 15, 16) permits the adjustment, without bias, of experimental data in such a manner as to minimize the effects of extraneous variables which might otherwise influence the result of an experiment. Where such variables are correlated with the responses to be measured, the effects of this correlation can be eliminated, the resulting effect on experimental error being related to the magnitude of the observed correlation in the population concerned.

Certain correlated variable characters are apparently involved in most yield trials with fruit trees. Positive correlations between yields and size of trees have frequently been reported. The extensive literature on this subject in relation to deciduous fruit trees has been partially reviewed by Hoblyn (9), Overholser, Overley, and Barnhill (13), Wilcox (18), and by Yeager and Latimer (20). For citrus trees, correlated characters have been observed by Webber (17) and by Parker and Batchelor (14). Numerous reports have also indicated significant correlations between the yields of individual trees or plots of trees in different years or periods of years (5, 11, 12, 14, 20). Recognition of the existence of correlations between preliminary yields and tree size and experimental yields, has sometimes led to the utilization of independent variables in planning an experiment (1, 11, 14). Occasional attempts have been made to take advantage of the correlations by other methods which are less satisfactory than the more recent methods of covariance.

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Another possible application of covariance in the adjustment of yield data is in the handling of check-plot yields. Most of the traditional methods of using check-plot yields assume correlations between check-plot yields and test-plot yields, but in covariance the correlations are determined from the data.

Although it appears that the methods of covariance are superior for the adjustment of yield data on the independent variables named above, the value of these methods has not been determined extensively, especially in long-term orchard trials. The purpose of the present study was to determine, for a specific experiment at Riverside, California, (a) the effect of adjusting yields of orange trees by covariance, and (b) which of the independent variables available for this adjustment, or which combinations of them, would be of most value in the interpretation of treatment effects.

EXPERIMENTAL MATERIAL AND METHODS

The early history and plan of the experimental orchard has been described in detail by Batchelor, Parker, and McBride (2) and by Parker and Batchelor (14). Briefly, selected Washington Navel orange trees, in plots of eight trees each, were set out in 1917 and maintained as a uniformity trial, without fertilization, for a 10-year period. During this time, significant, positive interannual yield correlations were observed, as were also correlations between yield and top volume and area of cross section of the trunks (14).

The differential fertilizers were first applied in 1927 in 43 treatments of four plots each, the plots for each treatment having been selected in such a manner as to equalize mean yields for the preliminary period, 1922 to 1927 inclusive. The plots for each treatment were generally selected from four "yield groups" determined by arranging all plots in ascending order on the basis of their yields during the preliminary period, 1922 to 1927. An additional treatment was assigned to 25 check or "continuity" plots, chosen in such a way that the prior yield of each plot was approximately equal to the mean prior yield of a group of plots adjacent to it.

The equalization of the treatment means during the preliminary period might be expected to introduce an error into the interpretation by analysis of variance of the effects of differential fertilization (7), the size of this error depending upon the magnitude of the correlations of the experimental yields with the yields during the preliminary period, 1922 to 1927. In this study this correlation did not exceed 0.64 and it was usually about 0.45. Covariance provides a means of eliminating the effects of this correlation, however, regardless of its size, and is believed to be applicable to the data of the present experiment.²

For 12 years, 1928 to 1939, the annual fertilizer applications in the various treatments were applied essentially without change. Individual tree yields were obtained annually during this period, but the mean annual yields per tree for each plot constitute the data used in the analysis of treatment effects. Marked decreases in yield re-

²Personal interview with R. A. Fisher, 1936.

sulted when nitrogenous fertilizers were not applied; hence, in order to avoid complications in the analysis, due to treatments with unequal variances, two treatments which did not involve the application of materials containing nitrogen were omitted. This left 41 treatments of four plots each and the fertilized check treatment of 25 plots. The 12 years of experimental yields were divided into three periods of 4 years each, and the mean annual yields per tree per plot for these periods were computed. These means were used in the present study of the effects of covariance. It is expected that the methods found to be the most satisfactory for adjusting yield data for these three 4-year periods will be useful in adjusting the yield data of individual years for the efficient evaluation of treatment effects.

The independent variables which are available for the adjustment of the yield data are: (a) volume of the tops of the trees, ascertained in 1926, before the start of the differential fertilizer applications, by means of a calibrated tent draped over the tops of the trees; (b) the area of cross section at marked points on the tree trunks in 1926; (c) the annual yields of the trees for the period 1922 to 1927, when the trees were in the uniformity trial; and (d) the yields of the check plots during the years of the experiment.

The methods of analysis used were those of simple and multiple covariance, the procedures of which are available (6, 7, 10, 15, 16). In the present study, the effects due to the treatments have been eliminated, and the error term is in reality that caused by variation between plots within all treatments. In the unadjusted data, there are 123 degrees of freedom available for the estimation of the error variances. The application of covariance necessarily causes a reduction in the number of degrees of freedom for error equal to the number of independent variables used. For the sake of brevity, the results of adjustment are reported simply as the percentage reduction in the error variance resulting from the use of covariance on the various independent variables.

The variance of the difference between adjusted treatment means, when calculated by covariance methods, is subject to a correction, owing to the variance of the error regression coefficient which is used in estimating it (19). W. G. Cochran has kindly given us a factor by which the residual error variance (per plot) remaining after application of covariance may be multiplied to take into account the aver-

age effect of this variance.³ This factor is $\left(1 + \frac{m}{N_r - m - 1}\right)$, where m rep-

³Regarding the derivation of this factor Professor Cochran says:

"If y is the experimental yield on any plot, and x is the independent variate (i. e., the check plot yield or previous yield), the difference between two adjusted treatment means may be written

$$(\bar{y}_1 - \bar{y}_2) - b(\bar{x}_1 - \bar{x}_2), \quad (1)$$

where b is the regression coefficient. As shown in (19), the estimated variance of this difference is

$$2s^2 \{1 + r(\bar{x}_1 - \bar{x}_2)^2 / 2E\} / r \quad (2)$$

where s^2 is the adjusted error variance, r is the number of replicates, and E is the

resents the number of independent variables eliminated, and N_e , the number of degrees of freedom used in estimating the unadjusted error variance. The correction has been applied to all computations of adjusted error variance. A 50 per cent reduction in error variance, due to adjustment, doubles the efficiency of the experiment; that is, it results in the same precision with four plots per treatment as would be obtained with eight plots per treatment without adjustment.

DISCUSSION OF RESULTS

It was desirable to determine the effect on experimental error variance of the original distribution of the plots into four "yield groups" based on the uniformity yields during 1922 to 1927. This was done by analysis of variance, the error term losing 3 degrees of freedom as a result of the elimination of "yield-group" effects.

From line 1 of Table I it may be seen that the reduction in error

TABLE I—REDUCTION IN ERROR VARIANCE OF EXPERIMENTAL YIELDS BY APPLICATION OF COVARIANCE ON FOUR INDEPENDENT VARIABLES, WITH AND WITHOUT THE ELIMINATION OF "YIELD-GROUP" EFFECTS (ADJUSTED FOR THE AVERAGE EFFECT OF THE VARIANCE OF THE REGRESSION COEFFICIENT ON THE VARIANCE OF DIFFERENCES BETWEEN TREATMENT MEANS)

Line	Adjustment by Covariance	"Yield-Group" Effects	Reduction in Error Variance* (Per Cent)			
			1928-1931	1932-1935	1936-1939	Mean
1	None	Eliminated	34.90	10.19	15.47	20.19
2	On prior yield, 1922-1927	Not eliminated	39.53	15.84	19.60	25.02
3	On prior yield, 1922-1927	Eliminated	39.16	16.69	20.59	25.48
4	On 1926 top volume	Not eliminated	0.98	1.90	5.02	2.64
5	On 1926 top volume	Eliminated	33.00	8.87	14.97	18.95
6	On 1926 area cross section of trunks	Not eliminated	0.67	3.69	5.18	3.18
7	On 1926 area cross section of trunks	Eliminated	31.98	9.85	15.34	19.06
8	On check-plot yields	Not eliminated	33.95	24.51	13.52	23.99
9	On check-plot yields	Eliminated	46.25	25.42	21.79	31.15
10	On prior yield 1922-1927 and check-plot yield†	Not eliminated	48.73	28.22	24.76	33.90
11	On each of the four variables named above	Not eliminated	48.47	26.27	22.26	32.33

*Unadjusted error variance ("yield-group" effects not eliminated) for the different periods was as follows: 1928-1931, 310.5203; 1932-1935, 569.3659; 1936-1939, 544.7600.

†Adjusted by multiple covariance.

error sum of squares of x . If this expression is averaged over all possible pairs of treatments, the result will be found to be

$$2s^2 \{1 + t/N_e\} / r \quad (3)$$

N_e being the number of error degrees of freedom (before adjusting for covariance) and t and e the treatment and error mean squares of x . Now if the sampling error in the regression coefficient were ignored, we would use simply $2s^2/r$ as our estimate of the error of the treatment difference. Hence the correction factor is $(1 + t/N_e)$. If treatments have no effect on the x variate, the quantity t/e follows Snedecor's F -distribution, and its mean value is known to be $N_e/(N_e - 2)$, giving the result in the text for a single independent variate. For more than one independent variate, the general formula given above follows from results proved by Hotelling (Ann. Math. Statist. 1931, p. 360). While expression (3) is always valid, the formula given in the text is a good approximation only if the treatments have no effect on x . In the present case the formula may slightly overestimate when adjustments by previous yields are being considered, since the previous treatment yields for 1922 to 1927 were equalized amongst treatments."

variance, due to elimination of "yield-group" effects, was quite variable in the three experimental periods (highest in the 1928 to 1931 period), and that the mean reduction was about 20 per cent. It is desirable to compare this reduction with the effects produced by adjusting the yields during the test periods by means of covariance on the yields during the uniformity trial, 1922 to 1927. In this case, mean reduction in error variance (Table I, line 2) amounted to about 25 per cent. An additional application of covariance on yields of 1922 to 1927, combined with the elimination of "yield-group" effects, gave about the same degree of reduction (Table I, line 3) as did the use of the covariance alone. Although much of the value of the design of the experiment, on the background of the 1922 to 1927 prior yields, is obtained without the use of covariance, its application on these yields is a superior method.

The data of Table I also show that the effects on error variance of adjustment by covariance on 1926 top volume or on 1926 trunk area of cross section are slight (Table I, lines 4 and 6, "yield-group" effects not eliminated). Although the data of the uniformity trial indicate sizeable correlations between tree size in any one year and yield in the same season (14, p. 146), the correlations (for error, "yield-group" effects not eliminated) between size measurements as of 1926 and the yields in the three subsequent periods of 4 years each are found to be positive but never to exceed 0.2593. Apparently, correlations between these measures of initial tree size and yield in subsequent years are not sufficiently high in this experiment for adjustment by them to be of much value. This is further indicated by additional data in Table I, showing the reduction of error variance when "yield-group" effects are eliminated and when covariance on 1926 top volume or area of cross section is also carried out. Lines 5 and 7 of this table indicate that error variance is reduced by about the same amount simply as a result of the elimination of "yield-group" effects.

Another independent variable available for adjusting the experimental yields is the yield of check plots in the experimental periods. When adjustment was made by covariance on this variable, the reduction in error variance (Table I, line 8) was about 24 per cent, which indicates that local variations were important during the experimental period. These variations in different areas presumably arose from several causes, such as temperature, wind and other climatic differences, pests and pest control, soil-moisture conditions, et cetera. When the effects of "yield groups" based on the yields in the uniformity-trial period were also eliminated, a further reduction in variance, to about 31 per cent (Table I, line 9), occurred. It appears, therefore, that local variations which were not of a permanent nature, as well as rather permanent variations typified by the prior yields in 1922 to 1927, were important sources of variation in yields during the experimental period.

An analysis by multiple covariance on the yields of 1922 to 1927 and on the concurrent yields of the check plots was therefore calculated. It was found that the error variance was reduced about 34 per cent (Table I, line 10), a slight improvement over the application

of covariance on check-plot yields coupled with the elimination of "yield-group" effects (Table I, line 9). An additional multiple covariance on all four independent variables (top volume, area of cross section, yields of 1922 to 1927, and check-plot yields) gave an error-variance reduction of about the same value (Table I, line 11). It was found in this last covariance study that only the standard partial regressions on prior yields and check-plot yields were significant. The values for these regressions are shown in Table II.

TABLE II—STANDARD PARTIAL REGRESSIONS FOR ERROR OBTAINED BY MULTIPLE COVARIANCE OF EXPERIMENTAL YIELDS ON FOUR INDEPENDENT VARIABLES; EFFECTS OF "YIELD GROUPS" NOT ELIMINATED

Independent Variable	Standard Partial Regressions		
	1928-1931	1932-1935	1936-1939
Top volume.....	-0.1322	-0.0957	-0.0210
Area of cross section of trunks.....	0.0019	0.0474	0.0108
Yield, 1922-1927.....	0.5167*	0.3674*	0.3753*
Check-plot yields.....	0.3540*	0.4008*	0.2654*

*Highly significant; $P < 1$ per cent.

It appeared that among the variables available for adjustment, only the yields during the period of the uniformity trial and the check-plot yields during the experimental periods were likely to be valuable in interpreting treatment effects, and that in this interpretation the effects of "yield groups" need not be eliminated. It therefore became important to determine the best use to make of the six annual yields of the uniformity trial.

In Table III, the reductions in error variance obtained by covariance on yields of individual years of the uniformity trial are presented

TABLE III—REDUCTION IN ERROR VARIANCE OF EXPERIMENTAL YIELDS AS A RESULT OF ADJUSTMENT BY COVARIANCE OF YIELDS IN THE YEARS OF THE UNIFORMITY TRIAL (1922 TO 1927); EFFECTS OF "YIELD GROUPS" NOT ELIMINATED (ADJUSTED FOR ERROR OF REGRESSION COEFFICIENT)

Covariance on:	Reduction in Error Variance (Per Cent)			
	1928-1931	1932-1935	1936-1939	Mean
Yield, 1922.....	6.12	0.20	-0.45	2.26
Yield, 1923.....	9.96	2.98	0.52	4.48
Yield, 1924.....	21.58	24.07	15.81	20.49
Yield, 1925.....	34.66	9.44	12.67	18.92
Yield, 1926.....	33.88	23.81	18.44	25.38
Yield, 1927.....	40.18	24.45	38.34	34.32
Sum of yields, 1926 and 1927.....	44.77	29.56	25.28	33.20
Sum of yields, 1925, 1926, and 1927.....	46.64	25.38	38.95	36.99
Sum of yields, 1924, 1925, 1926, and 1927.....	42.18	23.24	23.26	29.56
Mean of yields, 1922-1927.....	39.53	15.84	19.69	25.02
Yields, 1926 and 1927*.....	44.74	28.52	37.60	36.95
Yields, 1925, 1926, and 1927*.....	46.26	29.04	36.87	37.39
Yields, 1924, 1925, 1926, and 1927*.....	48.09	33.77	35.84	39.23

*Used independently in multiple covariance.

first. It is evident that adjustments based on yields of 1922 and 1923 had little effect. These were the first and second crops produced by the trees generally. This result was anticipated in the original report on the variability of yields during the uniformity trial (14, p. 106). It may be related to the young age of the trees at that time or to unfavorable weather conditions in 1922. The yields of the years 1924 to 1927, inclusive, used singly in covariance, were individually effective in reducing error variance from a mean of about 20 to a mean of about 34 per cent. Their value varied greatly in the three experimental periods, but adjustment tended to be more effective when made on yields of the later years of the uniformity trial. The greatest reduction in error variance was obtained by covariance on the yields of the last year of the uniformity trial, 1927.

It would appear that the use of prior yields for a series of years might provide a more reliable index for adjusting yields than the use of yields of any one year (4, 9, 12). Combinations of yields of the plots in prior years were therefore obtained by summation or by averaging. Adjustment on these sums (or means) caused the reduction in error variance indicated in the center section of Table III. The results are variable and not especially high in comparison with adjustments on the yields of 1927 alone. The greatest reduction was obtained when the sums of the prior yields for the three years 1925, 1926, and 1927 were used for adjustment. The use of all six years (1922 to 1927) of the uniformity trial (upon which the allocation of plots to treatments was originally based) gave the poorest result.

The agronomic investigations of Forester (8) suggest that multiple covariance on yields of two or more prior years might give results superior to those obtained by covariance on sums or means of yields of the same prior years. The former procedure probably gives a more accurate evaluation of seasonal effects. Such adjustments were accordingly made, the yields which were obtained, 1, 2, 3, and 4 years prior to the start of the differential treatments being used as independent variables. These multiple adjustments were found to decrease error variance to a greater extent and in a more consistent manner than the adjustment based on simple covariance on sums of yields, involving the same uniformity-trial data.

In comparing the effects of adjustment by covariance on yields of 1927, alone (top section, Table III), and by multiple covariance on yields of 1927 and other years, as indicated in the bottom section of Table III, it may be seen that there was a slight increase in precision as more of the preliminary years were used in the adjustment. This occurred in spite of the reduction in degrees of freedom available for the estimation of error variance with increasing numbers of independent variables. This increase in efficiency could not be expected to continue indefinitely, however; and the additional use of the yields of 1922 and 1923 could hardly be expected to improve the adjustment, because of the low (error) correlations between their yields and the yields of the three experimental periods, as suggested by the results previously given. In the covariance on the yields of the last 4 years of the uniformity trial, the partial regressions (Table IV) on yields of 1924, 1925, and 1926, are each significant in two of the three

TABLE IV—STANDARD PARTIAL REGRESSIONS FOR ERROR OBTAINED IN MULTIPLE COVARIANCE OF EXPERIMENTAL YIELDS ON YIELDS OF FOUR INDIVIDUAL YEARS DURING THE PERIOD OF THE UNIFORMITY TRIAL (1922-1927); EFFECTS OF "YIELD GROUPS" NOT ELIMINATED

Independent Variables	Standard Partial Regressions		
	1928-1931	1932-1935	1936-1939
Yield, 1924	-0.2983*	0.4386*	0.0236
Yield, 1925	0.3949*	-0.4318*	0.0946
Yield, 1926	0.2372†	0.3084*	0.1099
Yield, 1927	0.3472*	0.2909*	0.5994*

*Highly significant; $P < 1$ per cent.

†Significant; $P < 5$ per cent.

test periods. Their signs, however, are not consistent. Only the regression on yields of 1927 was significant in all these periods.

The value of adjustment of the yield data on check-plot yields in the experimental years has been shown above. This variable is of such a nature as to be useful for control of error. It was therefore desirable to repeat the test of the effectiveness of covariance on the yields of the years of the uniformity trial, with check-plot yields used as an additional independent variable. The results of this study are given in Table V.

TABLE V—REDUCTION IN ERROR VARIANCE OF EXPERIMENTAL YIELDS AS A RESULT OF ADJUSTMENT BY MULTIPLE COVARIANCE ON CHECK-PLOT YIELDS IN THE EXPERIMENTAL PERIODS AND ON YIELDS OF YEARS DURING THE UNIFORMITY TRIAL; EFFECTS OF "YIELD GROUPS" NOT ELIMINATED (ADJUSTED FOR ERROR OF REGRESSION COEFFICIENT)

Covariance on Check-Plot Yields and on:	Reduction in Error Variance (Per Cent)			
	1928-1931	1932-1935	1936-1939	Mean
Yield, 1927	55.89	37.67	44.72	46.09
Sum of yields, 1926 and 1927	58.81	40.56	32.87	44.08
Sum of yields, 1925, 1926, and 1927	53.85	36.09	28.20	39.38
Sum of yields, 1924, 1925, 1926, and 1927	50.51	31.38	26.83	36.24
Mean of yields, 1922-1927	48.73	28.22	24.76	33.90
Yields, 1926 and 1927*	55.82	37.46	43.91	45.73
Yields, 1925, 1926, and 1927*	55.52	38.95	43.62	46.03
Yields, 1924, 1925, 1926, and 1927*	56.42	39.96	43.16	46.52

*Used independently.

Comparisons of comparable entries in Tables III and V show that the addition of check-plot yields as an independent variable consistently improved the adjustment. It tended, moreover, to make the results more regular. The results presented in Table V clearly indicate a tendency for the effect on error variance resulting from covariance on sums of yields in the uniformity period and on check-plot yields to decrease as the number of prior years utilized is increased. When the annual prior yields were used as independent variables, however, the reduction in error variance was not changed, materially, with the inclusion of an increasing number of the uniformity-trial yields in the

analysis; the reduction in error variance resulting from covariance on yields of 1927 and on check-plot yields, was as satisfactory as that resulting from covariance on yields of a larger number of years. The reduction resulting from application of multiple covariance on check-plot yields and on yields of 1927 was about 46 per cent, and was the greatest reduction obtained in these studies. It is of interest to note, however, that multiple covariance on yields of two or more prior years and on check-plot yields, was more effective than was covariance on sums of the same prior yields and on check-plot yields.

The standard partial regressions for error obtained in multiple covariance of experimental yields on check-plot yields and on yields of individual years in the last 4 years of the uniformity trial, are given in Table VI. They show that the annual yields of the uniformity trial

TABLE VI—STANDARD PARTIAL REGRESSIONS FOR ERROR OBTAINED IN MULTIPLE COVARIANCE OF EXPERIMENTAL YIELDS ON YIELDS OF FOUR YEARS DURING THE UNIFORMITY TRIAL (1922–1927) AND ON YIELDS OF THE CHECK PLOTS IN THE EXPERIMENTAL PERIODS; EFFECTS OF "YIELD GROUPS" NOT ELIMINATED

Independent Variables	Standard Partial Regressions		
	1928–1931	1932–1935	1936–1939
Yield, 1924	-0.2300*	0.2703*	-0.1280
Yield, 1925	0.2328*	-0.3766†	-0.0538
Yield, 1926	0.1227	0.2157*	0.0473
Yield, 1927	0.4508†	0.3327†	0.6509†
Yield of check plots	0.3508†	0.3130†	0.3113†

*Significant; $P < 5$ per cent.

†Highly significant; $P < 1$ per cent.

are not equally correlated with the yields in the various periods of the experiment. The partial regressions on check-plot yield and on the yields of 1927 are the only ones which are highly significant ($P < 1$ per cent) in all periods; the yields of each of the other three uniformity trial years have significant effects in one or more of the periods, but their signs are not consistent.

SUMMARY AND CONCLUSIONS

The data of a fertilizer experiment laid out in an orchard of Washington Navel orange trees, with a background of prior yields obtained during a 6-year uniformity trial, have been subjected to studies to determine satisfactory methods of adjusting experimental yields for the efficient evaluation of treatment effects.

Experimental yields, in three periods of 4 years each, were studied by methods of covariance on various independent variables. Results are reported in terms of the error variance which is applicable to the estimation of the average variance of differences between treatment means. It is shown that the use of covariance on the yields of the uniformity trial resulted in a reduction in experimental error. The reduction caused by such an adjustment was greater than that result-

ing from an elimination, by analysis of variance, of the effects of "yield groups" based on the same prior yields. Covariances on the indices of tree size, area of cross section of trunks, and the volumes occupied by the tops of the trees, at the beginning of the experimental period, did not reduce error appreciably; but covariance on yields of check plots during the experimental period was valuable in this respect. The error variance was reduced to a greater extent by multiple covariance on prior yields and on check-plot yields than by simple covariance on either of these independent variables.

It is concluded that rather permanent variations which are correlated with the yields during the uniformity trial, and also that variations of a more temporary nature, which affect areas of the orchard and are reflected by the yields of check plots, are responsible for an important part of the variability in the experimental yields.

In a further study of the six annual yields during the uniformity trial, in relation to yields in the three experimental periods, it was found that covariance on yields of the last 4 years of the uniformity trial were individually effective in reducing error; and that covariance on the yields of the last year of the preliminary period was the most effective. When sums (or means) of the annual prior yields of plots were used in covariance, or in multiple covariance with the yield of check plots as an independent variable, the effectiveness was generally less than when covariance was on the yields of the last year of the preliminary period. The reduction in error variance decreased as the number of annual prior yields used was increased. The use of the annual uniformity-trial yields as independent variables in multiple covariance was superior to the use of sums of the same uniformity-trial data. When check-plot yields were not utilized, the independent use of the annual prior yields resulted in slightly greater reductions in error as the number of prior yields was increased to four. When check-plot yields were also included in the covariance, however, practically equal reductions in error were obtained by independent use of the yields of the final year of the uniformity trial and by similar use of yields of the last 2, 3, or 4 years of that period.

The study indicates that in the 12 years of this experiment, the interpretation of yield effects as influenced by fertilizer treatments, by means of covariance, could be most accurately made by using the concurrent yields of the check plots and the yields of the final uniformity-trial year as independent variables. When this covariance was applied, a mean reduction in error variance amounting to about 46 per cent resulted. This is equivalent to increasing the number of plots per treatment from 4 to a theoretical 7.4.

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The Relative Yields of Border Fruit Trees

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IN MANY experimental plots in orchards, which must be continued over long periods, losses of trees occur from various causes. A troublesome question then arises as to the effect of the extra space available to trees bordering these misses on their behavior. A related question, less often encountered, is the suitability of inclusion of trees at the edge of an orchard in experimental plots. These latter trees are usually ruled out, but there are circumstances in which their inclusion would be an advantage. It is therefore of some interest to evaluate this border effect.

A common assumption has been that one could expect about a 25 per cent increase in growth and yield by each tree adjacent to an empty tree space, on the basis that an increase of soil volume and of room for branch expansion of that proportion would be fully utilized. Such an assumption is apparently unwarranted. Allen (1) has shown that closely planted trees thinned after their growth had been checked by crowding never attained the size reached by trees planted at a greater distance. At the other extreme, trees planted far enough apart for maximum growth could not utilize additional space. Commercial orchards usually fall between these extremes, and the data presented here are from trees planted at standard distances for the species and district.

Data from five peach orchards in the two principal cling peach districts of California have been examined. The variability of each of these orchards is probably less than average, because they were picked for experimental use on the basis of apparent uniformity. It is, none the less, considerable. The coefficients of variability range from 4.5 to 21.6, calculated on blocks of about 180 trees, and including all treatments in each block. The latter figure is very high due to variable damage from floods in 1940-41. In only one of these blocks (orchard IV) were there enough missing trees to make comparisons between those adjacent to a space (hereafter designated as A trees) and those one tree away (hereafter designated as B trees). In this case, 27 pairs of trees were compared using Student's method. The average yield per tree for the A trees was 602 pounds, and for the B trees, 588 pounds. The difference, 14 pounds, is 2.3 per cent and the odds are 1.85:1.

Trees at the edge of the orchard were considered for all five situations. The border trees will be called C trees and those adjacent to them, D trees. The C trees in orchard I averaged 311 pounds per tree, the D trees, 312. The difference being only 1 pound, odds were not calculated. In orchard II, C trees averaged 243, D trees 287 pounds per tree for 12 pairs. The difference, 44 pounds, is 18.1 per cent and the odds are 293:1. Data for these border trees are available for only one year (1926), but these odds would normally be considered highly significant, and indicate inferiority of the border trees.

The data for orchard III show an interesting phenomenon. In the first year considered, 15 C trees averaged 225 pounds per tree; D trees

273. The difference, 48 pounds, is 21.3 per cent and the odds are 31 : 1. The following year the C trees averaged 240 pounds, the D trees 205. This 35-pound difference in the reverse direction from the preceding year is 17.1 per cent and the odds are 4.5 : 1 that it is significant. This example brings out two interesting points: first, that even with a species not much given to alternation of bearing, there may be enough to influence performance greatly; and, second, that the degree of variability in a given block is subject to variation from year to year. The order of magnitude of yields and of differences between plots is not greatly different in the two seasons, but the odds for these differences are disparate.

In orchard IV, 15 C trees averaged 513, D trees 476 pounds. The difference, 37 pounds, is 7.7 per cent and the odds are 2.6 : 1. Alternation in this block is not conspicuous and the above results are typical.

Orchard V contains a block in which yield records have been obtained only for 1941, the first year of treatment. Eighteen C trees averaged 350, D trees 270 pounds per tree. The 80-pound (27.6 per cent) difference shows odds of 95 : 1. Two series of 10 pairs of trees having equal treatment, compared in the same way, showed differences of 49 and 22 pounds, and odds of 30 : 1 and 2.6 : 1, respectively.

These data show that other factors than space available may to a considerable extent determine the yield of peach trees under commercial orchard conditions.

Pears present a similar picture. Orchard I showed high variability. An average difference of 40 pounds, or 25.8 per cent, between 32 pairs of C trees yielding 195 pounds and B trees 155 pounds showed odds of only 7 : 1. Three years later, the same trees averaged 101 and 91 pounds respectively and the 11 per cent difference gave odds of only 2 : 1.

Orchard II had nine pairs of A and B trees. Their average yields were 320 and 324 pounds per tree, a difference too small for consideration. Twenty-four pairs of C and D trees in the same block averaged 325 and 287 pounds per tree. The difference of 13.2 per cent gave odds of 14.5 : 1.

In orchard III, 10 A trees yielded 249 pounds, 10 B trees 304 pounds. Although the difference was 22.1 per cent, the odds were only 1.6 : 1. The 39 C trees in this block averaged 350 pounds against 305 for the D trees. The odds in favor of this 14.8 per cent difference being significant were 9.6 : 1.

The well-known characteristics of the pear, high variability and great adaptability to cultural conditions, would suggest the sort of picture these data present.

Data from two apricot orchards were examined. These data are tabulated in Table I.

The data for orchard I indicate that A trees can be used in these plots without application of a correction factor. There is no suggestion that the extra space has benefited them.

Orchard II is one of the more uniform blocks. Its coefficient of variability for 1941, the third year of differential treatment, was 6.7 for 186 trees, including all treatments. The A trees seem better than

TABLE I—DIFFERENCES BETWEEN BORDER AND ADJACENT APRICOT TREES

Orchard	No. Pairs	Year	Yields (Pounds Per Tree)		Difference	Per Cent	Odds
			A*	B			
I	12	1930	85	73	12	16.4	9.0:1
		1931	230	217	13	6.0	1.6:1
		1932	288	295	7	2.4	1.5:1
		1933	218	177	41	23.1	12.0:1
II	13	1940	226	173	53	30.6	23.0:1
		1941	295	246	49	20.0	30.0:1
II	28		C	D			
		1939	312	240	72	30.0	115.0:1
		1940	252	193	60	21.1	14.0:1
		1941	320	255	65	25.5	68.0:1
II	15		Row 2	Row 3			
		1940	220	216	4	1.9	1.8:1
		1941	265	227	38	16.7	120.0:1
II	15		Row 7	Row 8			
		1940	145	125	20	16.0	6.0:1
		1941	266	279	13	5.0	2.5:1

*A trees are adjacent to spaces left by missing trees, B trees next to them. C trees are border trees, D trees adjacent to them. Rows 2 and 3 and rows 7 and 8 are random selections across the treatments.

the B trees and the C trees better than the D. The danger of attributing the difference observed to position is illustrated by the figures for two pairs of rows taken at random across the treatments. Although rows 2 and 3 show no difference in 1940, odds of 120:1 are found that row 2 is higher than 3 in 1941. Taking the 1941 figures, row 2 has a lower percentage of increase over 3 than C has over D, but higher odds. Rows 7 and 8 show the behavior one might expect for their position, that is, essentially equal yields for the two years.

Horticulturists have frequently observed "border effects" in closely planted orchards and in those receiving inadequate nitrogen or water. In orchards planted at more suitable distances and receiving better care this effect tends to disappear. Whether or not the appearance of several gaps in an experimental block makes it necessary to discard data from trees adjacent to those spaces is a variable to be determined for each orchard. Certainly these data, and others examined in detail by Roessler (2), do not support the idea that general correction formulae can be used. The desirability or undesirability of including border trees in plots seems to be likewise a matter to be determined by the individual situation, at least so far as apricot, peach and pear trees are concerned.

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Studies of Alternate Bearing in the Apple¹

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THE commercial apple crop in Illinois fluctuates between an annual yield of 1,500,000 to 5,000,000 bushels. This difference is due in a marked degree to the biennial bearing habit of most of the commercial varieties now grown in the state. Since this is a difficult problem for growers to meet, the Department of Horticulture initiated studies to determine the possibility of correcting it (Project No. 107.6).

In connection with the experiments carried out in Illinois, it is of interest to note the results of a few other workers. Aldrich (1) working with vigorous trees secured an increased fruit bud formation (over checks) if the thinning was heavy enough and done before July 1. Aldrich and Fletcher (2) also report an increase in fruit bud formation following heavy thinning before bloom, and up to June 18, if the fruit leaf-ratio was above 20. Magness, Fletcher, and Aldrich (3) secured increased fruit bud formation from ringed branches that were thinned. The greatest response resulted from thinning before June 15. Marked differences were noted between varieties when thinned after June 15. Harley, Masure, and Magness (4) thinning to a fruit-leaf ratio of 1-70 up to 39 days after full bloom resulted in a good bloom the following year. Thinning as late as 68 days after bloom or to only a 1-50 fruit-leaf ratio, did not result in fruit bud initiation. Howlett and Fowler (5) recommended thinning within 1 month of petal fall in order to get a commercial crop the following year. Bobb and Blake (3) found in thinning 19-year-old Wealthy trees to a 10- to 12-inch spacing that there were sufficient fruit buds formed for a crop when the thinning was completed at the early pink bud stage. A 6-inch spacing at this date did not cause the trees to bloom the next year. With the above findings in mind it will be of interest to note the results reported in this paper as to the effect of time of thinning upon fruit bud initiation.

PERSISTENCE OF ALTERNATE BEARING

Data from four blocks of trees included in a ringing experiment started in 1927 illustrate the extent to which the yield of certain varieties may vary from year to year. These data include one block of Grimes ringed on the trunks June 5, 1934, and one check block each of Grimes, Jonathan, and Delicious. Referring to the average yield per tree, Table I, it will be seen that the Grimes check block started production with a light crop in 1934; this was followed with a larger crop in 1935 and a still larger one in 1936. Biennial bearing began with the heavy crop of 1936 and since then all trees in the block have produced heavy crops in the even numbered years. It is of interest

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to note that the Grimes trees ringed in 1934 have not produced as much in the "heavy crop" years as the check trees, also in the "light crop" years the yield from the ringed block has been greater than from the check trees. Apparently the ringing has had some effect in leveling off the cropping even though the trees were still distinctly biennial in production.

The data for Delicious show the extent to which alternation in production may occur in this variety on heavier soils in Illinois. Jonathan followed the same trend as Grimes and Delicious, but with this variety there is an indication that biennial bearing began with a lighter crop averaging only 128 pounds per tree.

The data presented in Table I illustrate the extremes which may be expected in biennial crops in the apple and also the persistence of this tendency once it has become established. Biennial bearing is often thought of as being a characteristic of old trees; it is of interest, therefore, to note that the yields summarized in Table I are for the first heavy crops borne by these varieties.

TABLE I—YIELD RECORDS SHOWING ALTERNATE CROP YIELDS OF THREE APPLE VARIETIES GROWING IN THE UNIVERSITY ORCHARDS AT URBANA

Variety	Number of Trees	Age in 1934	Average Annual Yield for an Eight-Year Period							
			1934	1935	1936	1937	1938	1939	1940	1941
Grimes*	14	12	83	415	43	585	337	889	485	1024
Grimes	14	12	90	126	459	173	1106	165	831	67
Jonathan	10	13	128	94	111	289	206	344	111	408
Delicious	14	14	9	222	39	402	13	436	3	564

*Ringed June 5, 1934.

THE EFFECT OF DEFRUITING UPON ALTERNATE BEARING

The defruiting experiment reported here was carried out with the object of studying tree response after a complete crop removal at different times from the first drop to fruit bud initiation. The results can be compared with thinning; that is, partial fruit removal during this same period in the experiments included in the next section. The trees used for defruiting were carefully selected for uniformity in size and the quantity of bloom in 1939. All of the trees were in good vigor and all were receiving comparable cultural care. Because of the crop loss or crop reduction from a freeze the previous year a week or so before bloom, it seemed that the "on" year might be intensified in these trees in 1939. Under these conditions, therefore, a heavy set would be expected the year of the defruiting and if the influence of the crop upon fruit bud initiation was very marked, it would be indicated in the quantity of fruit buds initiated.

In Table II a "snowball" bloom was given a rating of 100 with a lighter bloom estimated in relation to this as a base. In 1939, the first drop was over on May 19; the second drop on May 29, while the June drop took place between June 6 and 16. Fruit bud initiation took place in these trees after August 1 in 1939 as determined in a thesis study by Mr. O. K. Loomis (6).

TABLE II—THE EFFECT OF DEFRUITING AT DIFFERENT TIMES BEFORE FRUIT BUD INITIATION UPON THE QUANTITY OF BLOOM THE FOLLOWING YEAR*

Year	Delicious				Jonathan				Grimes			
	No. Fruits Re-moved	Tree No.	Per Cent Bloom	Yield (Pounds)	No. Fruits Re-moved	Tree No.	Per Cent Bloom	Yield (Pounds)	No. Fruits Re-moved	Tree No.	Per Cent Bloom	Yield (Pounds)
<i>Fruit Removed May 23—16 Days After Bloom</i>												
1938	10724	1	100	0	3247	1	100	3	16712	1	50	395
1939			100	85			100	62			100	89
1940			65	615			50	187			100	528
1941			25	409			15	198			100	1497
<i>Fruit Removed June 5—28 Days After Bloom</i>												
1938	5538	2	100	0	1877	2	100	15	4172	2	10	286
1939			100	28			100	41			100	115
1940			75	363			50	146			5	310
1941			25	356			100	156			100	1302
<i>Fruit Removed June 12—35 Days After Bloom</i>												
1938	6304	3	100	175	2865	3	100	22	3382	3	1	68
1939			100	16			100	22			100	10
1940			75	326			75	311			1	101
1941			25	262			5	339			100	1112
<i>Fruit Removed June 21—44 Days After Bloom</i>												
1938	3022	4	100	7	3147	4	100	66	4258	4	1	68
1939			100	10			100	18			85	41
1940			25	157			75	349			10	272
1941			50	668			5	332			10	1617
<i>Fruit Removed July 1—54 Days After Bloom</i>												
1938	2292	5	100	17	2629	5	100	251	5556	5	25	812
1939			100	30			100	36			95	79
1940			50	†			35	394			30	644
1941			25	867			100	772			100	1205
<i>Fruit Removed July 14—67 Days After Bloom</i>												
1938	3325	6	100	141	3539	6	100	33	5152	6	100	1026
1939			100	26			100	7			100	14
1940			25	†			50	287			80	875
1941			90	1114			100	622			75	1289
<i>Fruit Removed July 31—84 Days After Bloom</i>												
1938	4432	7	100	11	2888	7	100	280	4516	7	5	141
1939			100	4			100	2			100	8
1940			5	781			35	393			0	10
1941			100	304			100	354			100	1491

*Full bloom in 1939, the year of the defruiting was about May 6.

†Full crop—fruit not weighed.

In evaluating the results of this experiment consideration should be given to the production record of the trees. Previous to 1939, the Delicious trees were bearing biennially (1938), as will be seen from the bloom record, being the "on" year. When the 1938 crop was reduced by a pre-bloom freeze the trees came back the next year with a full bloom. The bloom record shows that Grimes tended to be off in 1938, but bloomed heavily in 1939. Jonathan, like Delicious, was in full bloom in 1938 and 1939. The yield records of 1939 reveal that some fruit was missed in defruiting. The number of fruits pulled off, however, shows that generally these trees had set a heavy crop.

Attention is directed to the "on" condition of the trees used in this experiment in 1939 as a result of the crop loss in 1938. The stage seemed set for a study of the effect of complete crop removal as

reflected in fruit bud initiation. Since these trees had been alternating previous to 1939, it seemed safe to assume that a crop as heavy as that which had set in 1939 (see number of fruit removed) would at least tend to induce a light fruit bud set for the 1940 crop if the load was left undisturbed. If, however, the trees are able to form fruit buds during a part of the defruiting period, especially the early part, it would seem that that portion would be suggestive of the time during which early thinning might be most effective in correcting the "off" year. The data in Table II can now be examined for each variety.

It will be seen, first, that the bloom (or fruit bud initiation) began to fall off on the Delicious trees which were defruited after June 12, about 1 month after bloom. Secondly, the period when Grimes responded to defruiting was short; note the light bloom in 1940 on all of the trees defruited after May 23. Thirdly, as would be expected, since Jonathan does not tend to alternate so definitely in this state, all of the defruited trees came back with a good bloom in 1940. While the bloom record and the yield are both given for 1940 and 1941, the relationship between the two does not seem to be very direct. The data from defruited trees check with the thinning experiments in indicating that as the season advances the influence of a developing crop upon fruit bud initiation becomes more pronounced. While it would have been desirable to have had more trees in a study of this kind, nevertheless, the data are fairly consistent for the trees selected. The bloom of these trees in 1939, after a heavy loss of flowers from the pre-bloom freeze in 1938, is also to be taken into account in this connection.

EFFECT OF TIME OF THINNING IN CORRECTING ALTERNATE BEARING

The studies on this phase of the problem were initiated in 1939 in order to check the effect of the time of thinning under Illinois conditions with the results obtained in other states. The experiments were centered around the commercial varieties which alternate to the greatest degree in this state. The time of thinning decided upon was as follows: during full bloom, after the first drop, after the second drop, and after the third (June) drop. When the set was light the last two thinnings were omitted in some of the blocks. In all of the experiments in bloom thinning, five flower clusters were removed and the sixth one was left on. At the other thinnings the crop was reduced to such a degree that the tree could size up the fruit to good commercial size with little reduction in yield. In some blocks a heavy drop followed the second thinning, resulting in a yield somewhat below the average. The counts made in some of the blocks showed a ratio of from 50 to over 100 leaves per fruit. Thinning experiments were set up in orchards where the trees were vigorous, of approximately the same size, well pruned, and receiving the same cultural and spray treatments.

1. *Duchess* (10)² *C. F. Heaton, Johnson County*.—In this orchard 17 trees were thinned at full bloom in 1940 and 17 after the second drop. The other thinnings were omitted in this block because of a light

²The number in parenthesis after a variety is the age of the trees in years at the time of thinning.

set. In 1939, all trees had produced a full bloom which was followed by a light set. In 1940, there was a 100 per cent bloom on all of the trees. The following year, regardless of treatment, all of the trees came back with a 100 per cent bloom.

In this same orchard, in another experiment, 16 trees each were included in three tests to determine the effect of the severity of thinning at full bloom on fruit bud initiation. All of the trees were thinned when in full bloom; in one block 75 per cent of the bloom clusters were removed, in the second 50 per cent, and in the third 25 per cent. The thinning was done in both 1939 and 1940. In both 1939 and 1940, all the trees carried a 100 per cent bloom but set lightly. All of the trees in this experiment were given a bloom rating of 100 per cent in 1941. Under the conditions neither the time nor severity of thinning influenced fruit bud initiation.

2. *Wealthy (22) Charles Ringhausen, Jersey County:*—In this orchard about half the trees for a number of years had bloomed profusely and set heavy crops in the even numbered years, the other half bearing in the odd numbered years. Some trees showed alternation of a part of the tree. In 1940, four trees with a 100 per cent bloom were thinned in full bloom and four each after the first and the second drops. The average production per tree in 1940 was: bloom thinned, 12½ bushels; thinned after first drop, 16 bushels; after second drop, 16 bushels; and for a representative tree outside the block, not thinned, 22 bushels.

In 1941, a count was made of all the spurs and all of the bloom clusters present on selected large limbs on each tree in the experiment. These counts showed that the following percentage of spurs blooming after each treatment: full bloom thinning, 20 per cent; after first drop, 15 per cent; after second drop, 26 per cent; and for the tree outside the block, 20 per cent.

In relation to this experiment in 1940 and again in 1941, a bloom record was taken on 103 trees outside the above experimental block but adjacent to it. Forty-four trees carried 100 per cent bloom, 31 no bloom, and the remainder had a bloom ranging between the two extremes. In 1941, 17 of the trees that were without bloom in 1940 had a 100 per cent bloom, 3 again had no bloom, and the others were rated as 80 to 90 per cent. Of the trees that had a 100 per cent bloom in 1940 and produced from 20 to 30 bushels, 3 came back with a 100 per cent bloom in 1941, 27 had no bloom, and the remainder were scattered between 50 and 5 per cent bloom. The fact that several of the trees outside the thinning block which were not thinned but carried a heavier load than the thinned trees came back with a partial bloom in 1941 indicates that some factor other than thinning was possibly responsible for the "comeback" of the thinned trees.

3. *Wealthy (23), 1939, L. M. Smith, Johnson County:*—In this orchard in 1940, four trees were thinned at full bloom, and four each after the first and second drops. In 1939, these trees had produced no bloom, but a 100 per cent bloom in 1940. The crop of 1940 would be considered heavy for the size and pruning given the trees, averaging 332 pounds from the trees thinned at bloom, 431 pounds for the second

thinning, and 333 pounds for the last one. In 1941, the trees had the following bloom record based upon an accurate count of the total number of spurs with bloom clusters: bloom thinning, 17 per cent; after first drop, 10 per cent, and after second drop, 7 per cent. The other Wealthy trees in this orchard which were not thinned in 1940, came back with a very scattering bloom in 1941. There seems to have been a slight response to early thinning in this instance.

4. *Yellow Transparent* (23), 1939, L. M. Smith, Johnson County:—In 1940, seven trees were thinned at full bloom and seven each after the first drop and the second drop. In 1939, the trees had carried a scattering of bloom. The bloom in 1940 was 100 per cent, followed by a relatively light crop on all trees. In 1941, a count of the spurs and blossom clusters showed a 35 per cent bloom on the bloom-thinned trees and a 10 per cent bloom after each of the other two thinnings. Transparent trees outside the thinning block in this orchard which bore a crop in 1940 did not bloom in 1941.

5. *Golden Delicious* (10), 1939, Charles Ringhausen, Jersey County:—The bloom in 1939 on all the trees in this orchard had been 100 per cent, which was followed by a light set and a light crop. The next year all the trees bore a 100 per cent bloom. In 1940, 10 trees were thinned at full bloom and 10 after the first drop. At each of the last two thinning-dates only injured or imperfect fruits were removed. The crop in 1940 was light on the entire block averaging just over a bushel per tree with no marked difference in yield between them. The percentage of the spurs with bloom clusters in the different treatments in 1941 was as follows: thinned at full bloom, 33 per cent; after the first drop, 43 per cent; after the second drop, 33 per cent; and after the June drop, 32 per cent. Trees outside the thinning block that had not been thinned in 1940 had about the same range in the amount of bloom in 1941 as did the trees that were thinned.

6. *Golden Delicious* (18), 1939, Frank Chatten, Adams County (19), Fred Hawkins, Jefferson County; (20), O. G. Jones, Brown County:—In the Chatten and the Hawkins orchards four trees were thinned at full bloom in 1939 and four each after the first, the second and the June drop. In the Jones orchard only the first two thinnings were completed on account of the light set. In all three orchards the trees had been alternating in varying degrees for some years. In 1939 there was a 100 per cent bloom in the three orchards on all the trees selected for thinning. The average yield per tree in bushels in 1939 in the Chatten orchard was: full bloom thinned, 15; after the first drop, 17; after second drop, 21½; and after June drop, 25. All the trees failed to bloom in 1940 but came back with a 100 per cent bloom in 1941. In the Hawkins orchard the average yield in bushels per tree in 1939 was: full bloom thinned, 11; after first drop, 17; after second drop, 25; and after June drop, 21. In 1940, there were no blooms on any of the trees but in 1941 the bloom rating was 100 per cent on all the trees.

The yield was 15 bushels per tree from the two thinning blocks in the Jones orchard in 1939. Other trees outside the plot bore a heavier crop. In this orchard there was a scattering bloom in 1940 on the trees

thinned at full bloom, those thinned after the second drop and also in the trees outside the block. In 1941, all of the trees in the orchard were given a rating of 100 per cent bloom.

7. *Golden Delicious* (18), 1939, F. E. Penstone, Pike County:—The records for this orchard are presented in tabular form in Table III, because they show that some of the trees produced a good bloom in 1940, the year after thinning, whereas trees of the same variety and about the same age in the other orchards failed to bloom that year. By referring to Table III, it will be seen that in 1939 the earliest thinning in this experiment was done in the "cluster bud" stage, some 2 weeks before full bloom, at which time 83 per cent of the clusters were pulled off. Each of the trees thinned at this time bloomed in 1940, and on three of them the bloom was heavy enough for a full crop; the other tree developed 1 per cent bloom. It is of interest to note that after the June drop thinning one tree came back with a 90 per cent bloom. It should also be noted that every tree in this experiment produced at least a few flowers in 1940 but that in 1941 all but three bore a full bloom.

There is a suggestion in this experiment of some effect upon fruit bud initiation from prebloom thinning, but one tree, thinned later, June 29, also developed a heavy fruit bud set during the high yield season of 1939.

TABLE III—SHOWING THE EFFECT OF TIME OF THINNING
UPON ALTERNATE BEARING

Time of Thinning	1939		1940*		1941†	
	Per Cent Bloom	Number of Fruits per Tree	Per Cent Bloom	Average Yield per Tree	Per Cent Bloom	Average Yield per Tree (Bu)
Cluster Bud April 16 to 18	100	3924	1	No record of yield	100	26
	100	2697	15		100	11
	100	823	40		100	12 ¹ / ₂
	100	2463	80		100	11 ¹ / ₂
After First Drop May 16 to 24	100	1190	Few		100	No record
	100	3722	Few		95	28
	100	2144	5		90	18
	100	2297	Few		85	30
After June Drop June 29 to 30	100	2473	Few		100	18
	100	3461	90		100	6
	100	1806	5		100	Dead
	100	2421	5		100	35
Late Thinning (Tree conditioning) August 4	100	1554	Few		100	24
	100	3255	Few		100	25
	100	3556	1		100	29 ¹ / ₂
	100	2666	Few		100	30

*No thinning in 1940.

†Date of thinning in 1941—after the June drop.

DISCUSSION AND CONCLUSION

Yield records of the first heavy crops of Grimes, Jonathan, and Delicious show a surprising persistence of the biennial bearing habit for seven crops in most trees when this tendency once becomes established. It should be emphasized that in these trees no attempt was made to correct the condition by cultural treatments and that the

biennial records are for unthinned trees. The annual yields reported for these varieties, therefore, may be looked upon as illustrative of the basic condition with respect to apple yields in the state as a whole.

The defruiting experiments were designed to see how far into the season a variety may come back with a bloom the following year if the crop were removed. Effect of crop on fruit bud initiation was found to vary with the variety. After a certain period, it is probable that when trees are bearing heavily, even a complete removal of the crop may not result in sufficient fruit bud initiation the current year to produce a crop the following year. Complete crop loss any time up to full bloom, however, from any cause usually results in a heavy bloom the following year. An extreme condition is thus apparently set up in the tree by a loss of bloom to the extent which took place in 1938 or by a heavy crop which reduces greatly or prevents fruit bud initiation.

The time of thinning experiments were designed to test the effectiveness of some of the leads reported elsewhere, under Illinois conditions, with our commercial varieties. The experiments were laid out in carefully selected blocks in commercial orchards and the severity of the thinning was purposely designed to leave a full crop upon the tree. It seemed in planning the work that it would be desirable in the first series of experiments on account of the added expense to determine whether or not early thinning was effective when there was a full crop upon the tree. The defruiting experiments fitted into this picture. It will be seen then that the early thinning under the conditions of these experiments was not effective in correcting biennial bearing. It is clear then that this procedure will have to be supplemented by cultural treatments and a greater reduction of the crop in the "on" year than was practiced in these experiments.

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A Chlorosis and Necrosis of Tung Leaves Associated with Low Potassium Content¹

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IN THE early part of August 1941 the authors' attention was called to an area in a tung orchard at Capps, Florida, that was severely affected with interveinal chlorosis and necrosis of the leaves. As a mineral deficiency was suspected, samples of these leaves were collected and analyzed for various mineral constituents (Table I). A

TABLE I—ANALYSES OF TUNG LEAVES FROM THE CAPPS, FLORIDA, ORCHARD*

Condition of Leaves	Constituents On a Dry-Matter Basis					
	Ash	K	N	Ca	Mg	P
	<i>Per Cent</i>	<i>Per Cent</i>	<i>Per Cent</i>	<i>Per Cent</i>	<i>Per Cent</i>	<i>Per Cent</i>
Necrotic (1)†.....	9.49	0.37	1.90	2.55	1.10	0.17
Necrotic (2).....	8.73	0.35	2.04	2.28	1.11	0.17
Chlorotic (1).....	8.45	0.35	1.72	2.26	0.98	0.15
Chlorotic (2).....	9.05	0.35	1.70	2.47	1.03	0.15
Normal.....	8.86	0.66	2.13	2.41	0.60	0.13
Normal.....	8.68	0.62	2.02	2.37	0.66	0.13

*Samples were collected in mid-August, 1941. Each sample is a composite from at least 10 trees and consists of mid-shoot leaves from non-bearing terminals.

†Duplicate samples collected in the field indicated by (1) and (2).

striking feature of these analyses is the low content of potassium in both the chlorotic and necrotic leaves as compared to normal leaves from an adjacent area in the same planting.

LEAF SYMPTOMS

The leaf pattern associated with the low potassium content is characterized by partial chlorosis or necrosis between the veins. The leaves at the base of the terminal shoot are generally affected first and later the symptoms advance toward the apex. Yellow areas appear at the margin of the leaf between the veins and later extend inward in an irregular series of patches. Often the entire margin of the leaf is chlorotic (Fig. 1).

Leaves on many of the trees show an interveinal necrosis. The entire margin of the leaf usually has dead, ragged tissue and the necrosis extends inward between the secondary veins almost to the main vein. The margins tend to curl up, the leaf becomes very brittle and finally is abscised prematurely. Apparently the necrosis is an advanced stage, although it may develop at the beginning in a pattern similar to the chlorotic pattern, but without going through the chlorotic stage.

In the Capps, Florida orchard where the symptoms were first observed in mid-August both the interveinal chlorosis and necrosis

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FIG. 1. Tung leaves showing (1) above, interveinal necrosis; (2) below, interveinal chlorosis associated with low potassium content.

have leaf patterns similar to those found at the Capps orchard. Leaf and soil samples were collected from these orchards for analysis. Samples were obtained from the affected trees in the orchard and from the unaffected ones if there were any. In addition, samples were obtained from an orchard in the same general region not affected with the interveinal chlorosis or necrosis.

METHODS

Each leaf sample consisted of a composite of several leaves without the petioles from each of at least 10 trees. These leaves were always taken from about the middle of non-bearing terminals. Badly necrotic leaves were avoided as a general rule. The samples were dried at 70 degrees C and ground in a Wiley mill. A 10-gram sample was ashed in a muffle furnace for 8 hours at 500 degrees C. The ash was digested on the steam bath in 1:1 HCl for 2 hours, the small amount of silica and unburned carbon filtered off, and the filtrate made up to a volume of 100 milliliters. Suitable aliquots were taken for the various determi-

were prevalent. In another orchard near Monticello, Florida in mid-August, only the chlorotic pattern was observed and that mainly on the basal leaves. When the same orchard was visited about 1 month later, the necrotic condition was much in evidence and a large number of leaves on the terminals showed both the chlorotic and necrotic condition. Usually the leaf symptoms are more striking on the bearing terminals than on the non-bearing ones. Apparently they do not become noticeable until the season is well advanced and are most prevalent in the fall.

FIELD SURVEY

About the middle of September, a survey was made of a number of commercial orchards in South Georgia and West Florida which had been previously observed to

nations. Calcium was precipitated as the oxalate and titrated with standard KMnO_4 . Magnesium was determined by titrating the magnesium ammonium phosphate precipitate with standard acid. Phosphorus was determined by the colorimetric procedure using ammonium molybdate and stannous chloride. Potassium determinations were made according to the method of Hibbard and Stout (8) with the modification that ceric sulfate was used instead of potassium permanganate as the oxidizing agent. Nitrogen was determined by the Kjeldahl-Gunning method.

LEAF ANALYSES

In Table II are presented the data from the analyses of the leaf samples from orchards in the general region in which interveinal chlorosis and necrosis were evident. The outstanding feature of these data is the low content of potassium in the leaves affected with interveinal chlorosis and necrosis as compared with normal leaves from the same general area. Except for the Cairo, Georgia, orchard No. 2, the potassium content of the affected leaves was .42 per cent or less. In this orchard only the chlorotic pattern was in evidence and the leaf samples averaged .57 per cent of potassium. The lowest potassium content was in leaves from the Attapulcus, Georgia, orchard which had only .24 per cent of potassium. This orchard was more severely affected than any other in the survey. In one part of the orchard, however, the trees were affected only slightly and a sample of normal leaves from there contained .61 per cent of potassium, about two and one-half times as much as the affected leaves. Normal leaves from orchards in the same general area on the same or similar soil type ranged from 0.80 to 1.01 per cent of potassium in the leaves. The 11 samples of affected leaves had a mean potassium content of 0.34 per cent. The mean of the four samples of normal leaves was 0.84 per cent. Comparing these as independent samples (7), the difference is highly significant, the value of "t" being 5.87, where a value of only 3.01 is required for significance at the .01 point.

In one of the affected orchards experimental plots of young trees have been established in which a mulch of about 35 pounds fresh weight per tree of *crotalaria* and native grasses is being compared with clean cultivation. The two treatments are in alternate rows. It was noted that the trees in the clean-cultivated rows showed considerable interveinal chlorosis of the leaves and some necrosis, whereas the trees in the mulched rows were relatively free of the symptoms. Leaf samples were collected from the trees in these plots for analysis and the data are presented in Table III.

It is to be noted that the leaves of the mulched trees contain more than twice as much potassium as those of adjacent clean-cultivated trees. Here again the low potassium content is associated with the interveinal chlorosis of the leaves. It is probable that the mulch contained sufficient soluble potassium compounds available to the trees to prevent the chlorotic condition from becoming prevalent. The value of a mulch as a source of potassium for orchard crops has been emphasized in recent years by several workers (1, 13, 16).

TABLE II.—ANALYSES OF TUNG LEAVES FROM ORCHARDS IN LOCALITIES WHERE INTERVEINAL CHLOROSIS AND NECROSIS WERE EVIDENT

Orchard Location	Soil Type	General Condition of Leaves in the Locality of Sampling	Age of Trees (Yrs)	Constituents on a Dry Matter Basis (Per Cent)					
				Ash	K	Ca	Mg	P	N
Monticello, Fla. No. 1	Ruston fine sandy loam	Predominantly interveinal chlorosis. Some interveinal necrosis	4	9.52	0.42	2.57	0.85	0.14	1.96
Monticello, Fla. No. 2 (1)*	Ruston fine sandy loam	Predominantly interveinal chlorosis. Some interveinal necrosis	4	11.52	0.34	1.97	1.55	0.12	1.90
Monticello, Fla. No. 2 (2)	Ruston fine sandy loam	Predominantly interveinal chlorosis. Some interveinal necrosis	4	11.08	0.37	1.95	1.48	0.11	1.77
Lloyd, Fla. (1)	Red Bay fine sandy loam	Both interveinal chlorosis and necrosis prevalent	3	10.48	0.32	3.09	0.83	0.17	2.46
Lloyd, Fla. (2)	Red Bay fine sandy loam	Both interveinal chlorosis and necrosis prevalent	3	10.82	0.30	3.03	0.88	0.16	2.29
Cairo, Ga. No. 1 (1)	Red Bay fine sandy loam	Predominantly interveinal chlorosis. Some interveinal necrosis	7	11.83	0.34	3.50	0.92	0.16	1.96
Cairo, Ga. No. 1 (2)	Red Bay fine sandy loam	Predominantly interveinal chlorosis. Some interveinal necrosis	7	14.20	0.31	3.43	1.18	0.15	1.94
Cairo, Ga. No. 2 (1)	Red Bay fine sandy loam	Almost entirely interveinal chlorosis	7	9.38	0.64	1.24	0.42	0.10	1.57
Cairo, Ga. No. 2 (2)	Red Bay fine sandy loam	Almost entirely interveinal chlorosis	7	5.79	0.50	1.35	0.53	0.10	1.46
Atapugus, Ga. (1)	Red Bay fine sandy loam	Severe interveinal necrosis with some interveinal chlorosis	8	7.15	0.24	1.84	0.92	0.15	1.97
Atapugus, Ga. (2)	Red Bay fine sandy loam	Severe interveinal necrosis with some interveinal chlorosis	8	9.35	0.24	2.55	1.09	0.14	1.79
Atapugus, Ga.	Red Bay fine sandy loam	Normal	8	7.18	0.61	1.87	0.56	0.19	2.33
Lamont, Fla.	Ruston fine sandy loam	Normal	9	8.03	0.80	2.11	0.57	0.15	2.21
Monticello, Fla. No. 3 (1)	Ruston fine sandy loam	Normal	5	9.45	1.01	2.58	0.34	0.18	2.70
Monticello, Fla. No. 3 (2)	Ruston fine sandy loam	Normal	5	10.11	0.94	2.77	0.32	0.16	2.69

*Duplicate samples collected in the field indicated by (1) and (2).

TABLE III—ANALYSES OF TUNG LEAVES FROM MULCHIED AND CLEAN-CULTIVATED TREES (LLOYD, FLORIDA)

Treatment	Condition of Leaves	Age of Trees (Years)	Constituents on a Dry-Matter Basis (Per Cent)					
			Ash	K	Ca	Mg	P	N
Row 12, clean cultivated	More than 50 per cent of leaves affected with interveinal chlorosis	3	9.07	0.29	2.49	0.83	0.16	2.41
Row 16, clean cultivated	More than 50 per cent of leaves affected with interveinal chlorosis	3	11.60	0.31	3.48	0.89	0.16	2.19
Row 13, approximately 35 pounds fresh weight of mulch per tree each year for 2 years	Less than 5 per cent of leaves affected with interveinal chlorosis	3	8.45	0.62	2.33	0.51	0.14	2.75
Row 17, approximately 35 pounds fresh weight of mulch per tree each year for 2 years	Less than 5 per cent of leaves affected with interveinal chlorosis	3	8.98	0.68	2.50	0.50	0.14	2.77

From the limited data presented it is evident that the leaves affected with interveinal chlorosis and necrosis are abnormally low in potassium. Tables I, II, and III also indicate that the magnesium content of leaves is generally higher in the affected trees than in the unaffected ones. Analyzed as independent samples (7) the magnesium content of the samples of affected leaves given in Table II is significantly higher than that of the samples of normal leaves. This agrees with results obtained by other workers (3, 9, 15) who found that potassium-starved plants accumulate more magnesium than those supplied with adequate potassium.

It is also to be noted that the nitrogen content of the affected leaves is generally lower than that of normal leaves although there are some exceptions. The relationship between the content of nitrogen and potassium in normal tung leaves has not been determined as yet and the significance of the general tendency for the affected leaves to be low in nitrogen is not understood. In the Cairo, Georgia, orchard No. 2, where the nitrogen content of the leaves is lower than the others, it is possible that the potassium deficiency is complicated by a nitrogen deficiency. Some workers have found that when potassium is omitted from the nutrient solution the growing plants take up more nitrogen than when potassium is supplied, while other studies indicate that this relationship does not hold. Gildehaus (6) found no definite relation between potassium and nitrogen absorption while Thomas (14) found that supplying additional potassium to certain plants increased the absorption of nitrogen.

There is some indication from the data in Tables I and III that the phosphorus content is higher in the low-potassium leaves than in the leaves with a higher potassium content. A similar relationship has been found in other plants (3, 9). The data in Table II, however, do not indicate this same relationship.

The data presented here, together with some unpublished analyses, indicate that normal tung leaves from various parts of the tung belt range from about .7 per cent to over 1.2 per cent potassium. The range

from about .6 to .7 per cent is marginal between leaves of normal appearance and those showing the chlorotic and necrotic condition. Leaves containing less than .6 per cent of potassium generally show interveinal chlorosis and necrosis. It should be emphasized that these ranges in potassium content are tentative since they are based on a limited amount of data.

Lilleland and Brown (11) found that, in general, California peach leaves contained more than 1 per cent potassium, which is about the tentative limit for an adequate amount of potassium in the leaves of prune trees (1), apple trees (2, 12) and peach trees (4).

SOILS

The soils in the orchards showing interveinal chlorosis and necrosis of tung leaves associated with low potassium content are well-drained, well-aerated upland soils of the Red and Yellow Podzolic great soil group. Most of the affected orchards have been found on the Red Bay fine sandy loam. Affected orchards are also located on Ruston and Norfolk fine sandy loams. These are soils of the Coastal Plain which are recognized as having a naturally low fertility level and are usually low in both total and exchangeable bases. The sandy loams of the Red Bay, Ruston, and Norfolk series are recognized, however, as potentially the most productive of the Coastal Plain soils. The exchangeable potassium was determined on soils in the orchards in which the trees showed interveinal chlorosis and necrosis of the leaves. It was found that in general the exchangeable potassium of all of the soils, both in the affected and unaffected areas, is low, averaging about 30 parts per million in the surface 12 inches. There was not much difference in exchangeable potassium between the affected and unaffected areas of the same orchard and therefore there was no correlation with the leaf content of potassium. In the case however, of the Lamont, Florida, orchard, which has not shown any interveinal chlorosis, the exchangeable potassium level of the soil is somewhat higher than in the orchards showing the symptoms, averaging about 50 parts per million in the surface 12 inches.

It is not necessarily to be expected that the exchangeable potassium content of the surface soil will always be a measure of the potassium available to the trees. There are a number of factors which might influence the uptake of this element such as aeration, drainage, available non-replaceable potassium, potassium level of the lower layers, nutrient balance, and others. In these well-drained, well-aerated soils having a generally low potassium level it is possible that the nutrient balance is of considerable importance. Much work has been done in recent years on the effect of other elements on the uptake of potassium. For example, Davidson and Blake (4) found in sand culture experiments with peaches that a high concentration of calcium with 10 parts per million of potassium in the nutrient solution resulted in potassium deficiency symptoms, whereas trees receiving medium calcium and 10 parts per million of potassium did not show the symptoms.

Inasmuch as the affected areas were not brought to the attention of the authors until mid-August, it has not been possible this season

to determine whether the trouble can be corrected by potash fertilization. This will be done in 1942.

SUMMARY AND CONCLUSIONS

Interveinal chlorosis and necrosis of tung leaves have been described and shown to be associated with a low potassium content. It is believed that the symptoms are indicative of a potash deficiency. The effect of mulch in increasing the potassium content of the leaves and in preventing the development of the interveinal chlorosis tends to support the hypothesis that the interveinal chlorosis and necrosis described in the paper are the result of a potassium deficiency.

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Effects of Severe Water Deficits in the Date Palm Upon Fruit Development

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ABSTRACT

This material will be published in full as a U. S. D. A. Technical Bulletin.

SEVERE water deficits in bearing date palms were obtained by the omission of irrigations for 5 to 6 weeks, and the effects upon rate of leaf elongation and upon fresh and dry weight increase of fruit were determined.

Severe water deficits in the palms during June or during July (when rate of fresh weight growth was rapid), in comparison with relatively small water deficits of frequently irrigated palms, modified the fruit in several ways: 1. Reduced rate of fresh weight increase as soon as reduced rate of leaf elongation was observed. 2. Caused greater initial reduction in fresh weight than in dry weight growth. 3. Caused from 7 to 14 days earlier softening of flesh of fruit in the initial stages of ripening. 4. Reduced rate of dry weight accumulation just prior to and during ripening, but at a time when soil moisture had again become adequate. 5. Reduced final fresh weight and dry weight of ripe fruit. 6. Decreased percentage of fruits developing checking and blacknose.

Comparable water deficits in the palms during August or September (when dry weight growth was at a maximum), in comparison with relatively slight water deficits of frequently irrigated palms, modified the fruit in a different manner: 1. Caused more rapid decrease in fresh weight per fruit during its normal dehydration just prior to ripening. 2. There was no reduction in rate of dry weight accumulation in two out of three experiments. 3. Slightly increased percentage of fruits that developed serious ripe-shrivel, in two out of three experiments.

In general, however, severe water deficits in vigorous palms had very little effect upon the commercial grade of ripe fruit, except as the water deficits reduced grade by reducing fruit size or improved grade by reducing the percentage of fruits developing blacknose.

Some Nutrient Deficiency Symptoms of the Pecan

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VARIOUS types of scorplings, chloroses, and other abnormalities of pecan leaves have been observed in pecan orchards and groves throughout the pecan growing territory. The causes of many of these abnormalities are unknown. From experience gained principally with crops other than the pecan it is known that deficiencies of essential elements cause certain abnormalities which for a given species are more or less characteristic for each element (1). Apparently, the characteristics of the abnormalities caused by the deficiency of essential elements have not been described in the case of the pecan (*Carya pccan* (Marsh.) Engl. and Graebn.). In order that the characteristics of the deficiencies of the known essential elements might be recognized and differentiated one from another an experiment was started in 1938 in which pecan trees of the Burkett and Stuart varieties were grown in washed sand; one tree of each variety was supplied with all known essential elements, in comparison with one tree of each variety supplied with all but one of these elements respectively. The experiment was planned to establish and maintain deficiencies of phosphorus, potassium, magnesium, calcium, boron, sulphur, nitrogen, copper, iron, manganese, and zinc. The Burkett and Stuart varieties were used in this experiment because they are planted widely in Texas and Louisiana, respectively, and one or more forms of leaf scorch and other abnormalities have been observed frequently in each variety.

METHOD

Pecan trees which had been propagated and grown by a commercial nursery in the usual manner were carefully selected for uniformity. The top had grown one season from the scion bud and the roots four years from the seed. The top was approximately 5 feet tall and 1 inch in diameter just above the bud union. The extremity of the tap root was amputated leaving about 30 inches of root below its junction with the stem. At the largest point the tap root was approximately 2 inches in diameter. These trees were planted in washed glass sand in 55-gallon steel drums, which had a threaded outlet in the lower end. These drums previously contained linseed oil or turpentine and after the end opposite the one with the outlet had been removed, were thoroughly cleaned with a strong lye solution which was allowed to stand in the drums until the oil residue was loosened. The drums were then washed and rinsed thoroughly with water, dried, and painted inside with pure red lead paint, then with a coat of water resistant asphalt paint, and finally with a coat of spar varnish. The exterior was painted with a good grade of porch and deck paint. Drums for storage of the nutrient solutions were similarly prepared except that the exterior was painted with an outside white paint.

In order to protect the roots of the trees from excessively high temperatures in summer or low temperatures in winter, the drums were almost submerged in soil in the side of a steep bank of a bayou.

The outlet in the bottom of the drum was provided with a pipe connection which extended beyond the slope of the bank and provided drainage from the drums and permitted collection of the leachings. The inner side of the outlet was covered with a piece of copper screen coated with asphalt paint. The screen was in turn covered with a layer of washed pea size gravel.

The pecan tree was planted in the drum so that the lower end of the tap root was 2 inches above the bottom of the drum and the trunk was centered in the drum. The drum was filled with washed sand while the tree was held in that position. A sheet iron cover with a hole in its center through which the tree trunk extended was placed over the drum.

The trees were watered the first 3 years with nutrient solutions prepared according to the formula of the Rubidoux Laboratory given by Eaton (2). In 1941 it was found that the reaction of the drainage water was extremely acid, of the order of pH 3. In order to decrease the acidity of the nutrient solution, sodium nitrate was substituted for the ammonium sulphate and sufficient sodium hydroxide was added to bring the reaction of the prepared nutrient solution from pH 5 to pH 6.8. This change resulted in raising the reaction of the drainage water by two to three points or to between pH 5 and pH 6. The nutrient solutions were made with A.C.S. chemicals without further purifications, and distilled water furnished by Barnstead stills.

At first the nutrient solution was added to the cultural drums by the constant drip method. This method proved unsatisfactory because it was difficult to maintain a constant rate of flow and because of the poor distribution of the nutrient solution in the sand. The continuous drip method was discontinued and thereafter the nutrient solutions were added periodically in sufficient quantity to wet the entire volume of sand in the drum. The water was poured through a hole in the cover of the drum by use of a large funnel with a side outlet at the lower end of its stem which spread the solution over the entire surface of the sand in the drum. Nutrient solution was added twice weekly in early spring and in autumn and at 2-day intervals during the summer. The amount of solution added each time varied from 2 to 5 gallons, depending on the size of the tree. The drums were flushed out periodically with distilled water.

After the first year the experimental trees were enclosed within a high wire screen cage without a top in an effort to reduce injury to the foliage of the trees by insects. The screen also served to protect the trees from damage by strong winds. The screen wire was painted with a screen enamel to reduce the chances of some of the elements in the metal contaminating the experiment.

DEFICIENCY SYMPTOMS

During the first year after the experiment was started symptoms of the deficiency of boron were observed. Apparently the supply of the other elements in the trees was sufficient for their needs during the first year. Some of the other elements became deficient the second and third years and the deficiencies increased in acuteness as time progressed. Definite deficiency symptoms have developed where nitrogen,

phosphorus, potassium, magnesium, calcium, boron, and sulphur, were withheld. Some evidence of deficiency was observed where copper, iron, manganese, and zinc were withheld, but the symptoms are not considered sufficiently definite to describe at this time. The deficiency symptoms observed for a particular element are not identical for the two varieties although there are similarities.

Nitrogen:—The symptoms of nitrogen deficiency were very similar on both the Stuart and the Burkett trees. Evidence of mild deficiency of nitrogen was a general decrease in the green color of the leaves. As the deficiency became progressively more severe the color changed to a yellowish green, then greenish yellow, and finally a uniform yellow with little or no green tint. Usually the area of the leaf blade immediately adjoining the mid-vein and the secondary veins retained the green color longer than the interveinal area.

After a mild deficiency had appeared one season, the initiation of growth by the buds was delayed the following spring. The shoot growth was short and slender. The leaves were small and a pale green or yellowish green. The dwarfing seemed to affect all parts of the leaf as the small leaves were perfect in shape and the relative size of the leaflets was very similar to that of a normal leaf well supplied with nitrogen. The leaves lost their green color as the season advanced in stages similar to those previously described but within a shorter time. After the green color had almost entirely disappeared small reddish brown necrotic spots developed in the interveinal areas which gave the leaf a russet appearance. Necrosis of areas of the leaf blade occurred on the margin and on the tips of the leaflet. Later the leaflet dropped from the rachis. With each successive year, as the deficiency became more acute, the leaf size became progressively smaller, the shoots progressively shorter, and premature defoliation became more extensive; finally many shoots died, starting on the upper branches and progressing downward.

Phosphorus:—The first evidence of deficiency of phosphorus that was observed on the Stuart tree was a general unthrifty appearance. The following spring initiation of growth was delayed but after it started, although the shoots were slender, they grew normally in length. The leaves were a bright green. Later when the deficiency became more acute the color of the old leaflets changed to a dull green and then to a yellowish green and some parts of the leaflet entirely lost the green color. Small areas between the secondary veins died and turned brown. These areas became more numerous and gave the leaflet a bronzed appearance. Enlargement and coalescence of necrotic areas occurred and sometimes involved one fourth or more of the blade of the leaflet.

With more acute deficiency, the shoot growth was short and slender. A slight loss of green color occurred on the older leaves about the time necrotic areas appeared. The necrotic areas on the older leaflets were more prevalent at the tips but also occurred on the margin at various points between the tip and the base of the leaflet. The necrotic leaflets soon dropped from the rachis. The youngest leaflets on a rachis were often unaffected while the older leaflets on the same rachis were necrotic.

Deficiency symptoms of the leaves of the Burkett tree from which phosphorus was withheld were a lighter green color than normal and the leaflets were narrow and short. The following spring shoot growth was shorter than normal. The leaves were small, narrow, and yellow. Some necrosis occurred at the tips of the leaves. The leaves dropped from the tree in early summer. The death of the tree followed.

Potassium.—The first evidence of symptoms of mild deficiency of potassium on the Stuart tree was a bronzed appearance of the leaf and soon thereafter numerous minute reddish necrotic spots which gave the leaves a rusty appearance. Acute deficiency was characterized by loss of green color from the margin of the leaflet and this extended towards the mid-vein and towards the secondary veins. The loss of color was followed by necrosis at the leaf margin or in the interveinal area with the margin unaffected. In some instances all of the leaflets on the rachis were affected. In other cases only the older leaflets were affected. Premature defoliation was not general.

Deficiency of potassium apparently did not interfere with the growth of shoots or leaves for although definite symptoms of deficiency had occurred the previous season the leaves attained full size and normal shape and the shoots were usually plump and well developed. However, after the effect of two seasons of evident deficiency symptoms, growth from lateral buds was weak and fewer leaves than normal were produced.

The first evidence of potassium deficiency on the Burkett tree was a bright glossy green of the foliage. The next symptom observed was a twisting of the leaflet to the extent of one-half turn, the two sides of the leaf blade were folded upward and then curved downward and the rachis was bowed. The tree had much of the general appearance of a peach tree.

There was a loss of green color from the margin towards the mid-vein or from the interveinal area towards both the main vein and secondary veins. This loss of color occurred on the older leaflets first. The margin of the leaflet turned yellow and later died. Numerous necrotic areas also occurred within the leaf blade giving the leaf a rusty appearance. These areas coalesced, crossed the veins, and formed larger necrotic areas. When the old leaflets reached this advanced stage, young leaflets which were still green had small depressed water-soaked areas which soon turned purplish and then brown. Each successive year the symptoms appeared earlier in the season. Premature defoliation occurred only when the chlorosis and necrosis were very general. Following this extreme acuteness of the deficiency the tree died.

Magnesium.—The first appearance of magnesium deficiency on the Burkett tree was a bronzing of the leaf with loss of green color from the margin toward mid-rib and secondary veins. Minute dead spots occurred scattered throughout the leaf. As the deficiency became more acute bronzing and appearance of necrotic areas occurred without previous chlorosis. Necrosis occurred more frequently at the tip of the leaflet, progressing inward. Bronzing preceded and accompanied the necrosis. Practically every leaf on the tree was affected. Young

leaves developed necrotic areas before they attained full size. Defoliation followed. New growth then appeared and the new leaves developed areas that appeared water-soaked; these later turned brown and coalesced forming necrotic areas.

The magnesium deficiencies on the Stuart tree were characterized by chlorosis which occurred between the secondary veins of the younger leaflets on a rachis. These symptoms were very similar to those described for the deficiency of magnesium on other crop plants (1). The apical leaflets on a rachis were dwarfed as compared with the normal or the basal leaflets on a rachis. Shoot growth was dwarfed. This chlorosis was not observed on the Burkett tree.

Calcium:—The two calcium-deficient trees died the first year of the experiment. The replants were slow starting and made very little growth until after the hot weather of summer had passed. The leaves on these trees never attained normal size.

Early in the season the leaves of the Stuart tree from which calcium was withheld were dark glossy green color, darker than normal. Later in the season the leaves lost the glossy sheen, and some yellowing and bronzing occurred. The leaves were slightly wavy. The distal leaflets did not attain the size of the older leaflets on a rachis. The rachises of the leaves were very much shortened so that the pairs of leaflets were close together and overlapped somewhat.

The older leaves on the Burkett calcium-deficient tree appeared normal. The younger leaflets on a rachis were smaller than the older leaflets and also chlorotic. The young leaves showed mottling with light green to yellow spots between the veins. As the season advanced many leaves showed loss of green color at tips and margins. The younger leaves were more affected than older leaves. Late in the season necrosis of the tips of the leaflets occurred.

Boron:—The symptoms of the deficiency of boron on the Stuart tree took various forms as the degree of the deficiency increased. The first appearance of boron deficiency was the development of areas 1 to 2 millimeters in diameter that appeared water-soaked on otherwise normal leaves. These spots soon took on a purplish color and then changed to reddish brown. Later the spots became more numerous especially on the younger leaves, but most of the spots were no larger than those appearing with the mild deficiency. With still more acute deficiency the lowermost leaflets on a rachis developed normally but the distal leaflets were smaller. Apparently most of the limited supply of boron was utilized by the first leaflets formed on a rachis and later leaflets did not have sufficient boron for full development. The younger leaves as they developed were chlorotic. On an individual leaflet the chlorosis was uniform throughout.

When the deficiency of boron became more acute shoot development was curtailed. The first three or four nodes apparently grew normally and a complete leaf developed from each node although the distal leaflets were frequently small. As the shoot continued to extend the available boron was depleted and the shoot became progressively weaker with smaller leaves at each node and finally so weak that only rudimentary leaves formed. The internodes of the distal portion of the

shoot were very short. The buds formed on that portion died and later the distal portion of the shoot died. The leaf on the first node was a yellowish green and each successive leaf was more chlorotic than the preceding leaf until there was an entire absence of green color.

In the most acute stage of deficiency observed in these experiments there was no normal shoot or leaf development. Shoots were short and slender and the leaves were small, crinkled, and frequently only rudimentary.

The Burkett tree did not develop the mild deficiency symptoms but the first evidences of deficiency were leaves which were dwarfed, yellow, and chlorotic. These symptoms were very similar to those of severe rosette of pecan which condition has been controlled on orchard trees by applications of zinc. The terminal buds died, then the shoots, and finally the whole tree.

Sulphur.—Deficiency of sulphur resulted in symptoms which were similar for both varieties but which differed in some details. When the deficiency was mild the older leaflets on the Stuart tree developed to almost normal size and shape but those on the Burkett tree were slightly dwarfed and narrow. The younger leaflets of both varieties were yellowish green. As the deficiency became more acute on the Stuart there was a loss of green color from the younger leaflets. The oldest leaflets were last to be so affected. The loss of green color occurred first on the sides of the mid-rib and secondary veins and extended towards the interveinal area. This lack of uniformity gave the leaflets a mottled appearance. As the loss of the green color progressed there were small islets of green surrounded by yellow which caused the leaflets to appear as though peppered with green. As the deficiency increased from mild to acute the older leaflets also lost the green color in the same way as the younger leaflets. The leaflets of the Burkett tree lost the green color more uniformly over the entire area of the leaflets without the mottling effect.

When the deficiency became still more acute, small reddish necrotic spots developed which gave the leaflet a russett appearance. Later marginal burning occurred, and all of the leaves dropped from the tree and new very small yellow leaves appeared.

The symptoms of sulphur deficiency either as to dwarfing of the leaflets or loss of color were always more pronounced on the younger leaflets.

DISCUSSION

A cycle is general in the appearance of deficiency symptoms of each element. The acuteness of the deficiency of an element seems to have a marked influence on the time when the symptoms of deficiency first appear in the cycle and also on the interval of time elapsing between the various stages of the symptoms. When the deficiency is mild the symptoms may first appear rather late in the season and then only one or two stages may develop that year. As the deficiency becomes progressively more acute the first appearance of the symptoms may occur earlier and earlier in the season until they appear along with foliation. Under such conditions the interval between the stages in the cycle of

symptoms is shortened and in extreme cases the first and later stages of the symptoms may occur simultaneously or the final stages may occur at foliation without the occurrence of any of the earlier stages.

Deficiency of some elements affects the size and shape of the leaves and deficiency of other elements does not affect leaf development but affects the leaves after they are fully developed. The function of the particular element in the leaf and in other parts of the tree seems to be a factor which determines whether a deficiency of that element will affect the development of the leaf. The mobility of the element from one part to other parts of the tree seems to be another factor involved. If an element is necessary for leaf development, the supply of the element available governs the extent of the development of the leaf. Boron, nitrogen, and sulphur seem to be necessary for leaf formation but the effect of deficiency of boron differs greatly from the effects of deficiency of either of the other two elements. Deficiency of nitrogen or of sulphur results in small leaves which are nearly normal in shape and without malformations. Boron deficiency not only limits the size of the leaves but results in malformations and when very acute only rudimentary leaves are formed.

Deficiency of nitrogen seemed to limit growth generally. Old and young leaves had practically the same color indicating the supply of nitrogen was distributed uniformly. Deficiency symptoms appeared on the leaves after they were full size where phosphorous, potassium or magnesium was withheld. Even when the deficiencies of these elements were acute and the older leaves had necrotic areas in them young leaves were apparently unaffected. With deficiency of boron, sulphur or calcium the older leaves frequently developed to normal size without evident deficiency symptoms and the young leaves which developed later had symptoms of injury, indicating that the limited supply of these elements was utilized by the first leaves in their development and that translocation from them to younger leaves probably did not occur.

A deficiency of nitrogen, sulphur, boron, or calcium was associated with restricted growth of shoots, or of leaves or of both shoots and leaves; but where phosphorus, potassium or magnesium was deficient leaf size and shoot length was almost normal.

The Stuart tree from which phosphorus was withheld, the Stuart and Burkett trees from which potassium was withheld, and the Burkett tree from which magnesium was withheld formed leaves which were normal or nearly so even after acute deficiency symptoms had occurred the two previous years. These elements either are not necessary for leaf formation or they are sufficiently mobile to be transported from old to new tissues. That the latter may be the condition is indicated by the fact that young leaflets grew normally while old leaflets were deteriorating with the appearance of bronzing, chlorosis and necrosis. Dwarfing of the leaves did occur eventually on the trees deficient in these elements which at first appeared not to be necessary for leaf development. The dwarfing usually was progressive from year to year. The deficiency of the element may have interfered in some manner with the synthesis of carbohydrates.

There was no single abnormality of the leaf which alone was sufficiently characteristic of the deficiency of any one element to definitely identify the deficient element, but the association of several abnormalities aids in identifying the deficiency. Certain symptoms were identical for the deficiency of several elements. The development of areas or spots on the leaf having a water-soaked appearance which changed to a purplish brown and then to a rusty brown or reddish brown, was observed where potassium, magnesium or boron was deficient. A light green color of the entire leaf blade was observed with deficiency of nitrogen on both the Stuart and Burkett trees and with a deficiency of sulphur on the Burkett tree.

Necrosis of portions of the leaflet occurred when phosphorus, potassium, magnesium, sulphur, or nitrogen was deficient. A combination of several symptoms such as the loss of green color of the leaf, bronzing, and the development of necrotic areas on the leaflet occurred on the minus phosphorus Stuart, the minus magnesium Burkett and the minus potassium Stuart and Burkett. Although these were very similar yet differences occurred which distinguished one from another. The "peach-leaf" appearance on the minus potassium Burkett tree was very characteristic and distinguished this deficiency from all others. The minus potassium was still further distinguished from the minus magnesium on Burkett by the more pronounced loss of green color from the margins and interveinal areas towards the veins; on the minus magnesium Burkett, with acute deficiency, there was little or no preliminary loss of green color preceding necrosis. The manner and extent of necrosis was also different. Necrosis at the apex of the leaflet on the minus magnesium was more prevalent than on the minus potassium Burkett; and at the time defoliation occurred the necrosis on the minus magnesium was more extensive than on the minus potassium Burkett tree. For the Stuart variety a rusty appearance of the leaves on the minus potassium tree distinguished this deficiency from that of phosphorus as this symptom did not occur on the minus phosphorus tree. Loss of green color, bronzing and necrosis of the leaves varied in degree and amount for the two elements but not sufficiently so that one could make a diagnosis from these symptoms of deficiency.

The mild deficiency of sulphur resembled the mild deficiency of nitrogen in that the young leaflets in each case were a light green color; however, with sulphur deficiency the older leaflets had a darker green color than the younger leaflets, while with nitrogen deficiency both old and young leaflets had a uniform light green color. With more severe deficiency the differences were more distinct, especially in the Stuart variety, mottling occurred with sulphur deficiency, but with nitrogen deficiency the loss of green color was nearly uniform throughout.

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The Relationship Between Chlorosis of Macadamia Seedlings and Certain Chemical Constituents of Macadamia Seeds¹

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IT HAD been observed when macadamia (*Macadamia ternifolia* var. *integrifolia*) seeds were planted in sand cultures and were allowed to grow for a period of several months without the addition of any nutrient, that seeds from certain trees produced significantly more chlorotic seedlings than seeds from other parent trees. These results suggested that this difference may have been related to variations in the amount of certain residual nutrients in the seeds. It is the purpose of this paper to present data which show that there is a definite relationship between chlorosis of macadamia seedlings and certain chemical constituents of macadamia seeds.

EXPERIMENTAL

One hundred and twenty macadamia seeds were gathered from each of 22 bearing trees in a commercial orchard near Honolulu, T. H. in October and November, 1939. One hundred seeds from each lot were planted 3 inches by 3 inches in boxes of washed coral sand at the Pensacola Station of the Hawaii Agricultural Experiment Station, on November 25, 1939. The cultures were maintained under field conditions during the growth of the seedlings; no nutrients were added.

Previously in growing macadamia seedlings in nursery field trials and in sand cultures, a satisfactory method had been employed for evaluating the mean chlorotic value of any lot of seedlings. Each plant in the lot was placed into one of the following five classes, based upon the color and condition of the leaves: No. 1, No chlorosis; No. 2, chlorosis slight; No. 3, chlorosis moderate; No. 4, chlorosis severe; No. 5, chlorosis very severe. The mean chlorotic value of any lot was derived by dividing the sum of the products of the plant class number and the frequency of individuals in the class by the total number of individuals in the lot being considered, or

$$\text{mean chlorotic value} = \frac{\sum (\text{plant class number}) (\text{frequency})}{n}$$

Hence, for example, a mean chlorotic value of 1.00 would indicate every plant in the lot was green whereas a mean chlorotic value of 5.00 would indicate every plant was very severely chlorotic.

The mean chlorotic value of each lot of seedlings in the present investigation was determined by this method on April 24, 1940.

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This investigation was carried out while the author was a member of the Division of Horticulture, Hawaii Agricultural Experiment Station, Honolulu, T. H. The guidance of Dr. J. H. Beaumont, is gratefully acknowledged.

TABLE I—CERTAIN ASH CONSTITUENTS OF MACADAMIA KERNELS TAKEN FROM SEEDS FROM TWENTY-TWO BEARING MACADAMIA TREES

Parent Tree	Seedling Mean Chlorotic Value	Average Dry Weight Per Kernel (Gm)	Units Per Gram of Dry Tissue						Units Per Dry Kernel							
			Ash (Mg)	Iron (Gm-ma)	Manganese (Gm-ma)	Calcium (Mg)	Magnesium* (Gm-ma)	Potassium (Mg)	Phosphorus (Mg)	Ash (Mg)	Iron (Gm-ma)	Manganese (Gm-ma)	Calcium (Mg)	Magnesium (Gm-ma)	Potassium (Mg)	Phosphorus (Mg)
B-435	1.07	2.55	12.8	3.3	0.40	0.91	78.1	0.69	1.59	32.7	8.4	1.02	2.33	199	1.76	4.07
B-226	1.08	2.75	13.0	3.2	0.65	0.57	56.4	0.67	1.35	35.8	8.8	1.76	1.58	154	1.84	3.72
C-280	1.10	2.00	12.0	3.3	0.36	0.86	75.4	0.65	1.61	24.1	6.6	0.72	1.71	150	1.29	3.22
B-540	1.11	2.30	12.7	4.3	0.79	0.89	88.5	0.67	1.21	29.1	9.9	1.82	2.04	205	1.55	2.79
C-301	1.11	2.55	15.0	3.6	0.20	1.00	80.5	0.64	1.64	38.3	9.2	0.51	2.55	207	1.63	4.17
B-82	1.12	2.30	14.1	4.1	0.15	0.69	82.4	0.62	1.49	32.5	9.4	0.35	1.58	189	1.43	3.42
D-37	1.15	2.45	10.8	4.1	0.24	0.43	77.6	0.65	0.84	26.4	10.0	0.59	1.05	191	1.58	2.07
C-256	1.16	2.05	15.1	3.9	0.51	1.23	92.2	0.64	1.79	31.0	8.0	1.05	2.52	189	1.31	3.06
C-285	1.17	2.35	11.4	4.1	0.41	0.86	69.5	0.66	1.84	37.6	9.6	0.96	2.01	163	1.39	2.43
C-296	1.23	2.35	16.0	2.9	0.26	0.89	90.0	0.63	1.84	37.6	6.8	0.61	2.08	189	1.54	4.32
C-17	1.26	1.75	16.9	2.6	0.51	0.69	90.0	0.60	1.92	29.5	4.6	0.89	1.20	158	1.11	3.86
C-269	1.33	2.00	17.5	2.1	0.20	0.66	85.0	0.63	1.92	34.9	4.2	0.40	1.31	170	1.20	3.84
C-454	1.38	3.65	17.2	2.4	0.26	0.69	67.8	0.65	1.77	62.9	9.5	0.95	2.50	248	2.37	6.45
C-200	1.39	2.20	17.5	3.7	0.20	0.77	82.4	0.65	1.82	38.5	8.1	0.44	1.70	180	1.42	4.01
C-351	1.40	2.25	17.4	2.9	0.33	1.09	80.5	0.60	1.98	39.2	6.5	0.74	2.42	182	1.34	4.46
C-316	1.65	2.35	15.8	2.1	0.30	1.03	73.3	0.62	2.08	37.1	4.9	0.71	2.42	172	1.46	4.88
C-52	1.66	2.20	13.9	2.6	0.47	0.77	87.8	0.60	1.88	32.7	6.1	1.10	1.81	207	1.41	4.42
C-22	1.68	2.40	15.5	2.4	0.27	0.80	73.3	0.66	2.23	37.2	5.8	0.65	1.92	175	1.58	5.35
C-72	1.72	2.15	13.8	2.5	0.48	0.91	87.1	0.55	2.45	34.0	5.4	1.03	1.97	187	1.18	5.26
C-397	2.46	1.50	13.3	2.1	0.11	1.06	74.3	0.59	2.32	19.9	3.2	0.17	1.59	111	0.88	3.48
C-453	2.63	2.15	15.4	2.1	0.11	1.06	82.4	0.63	1.86	32.3	4.4	0.23	2.22	172	1.32	3.91
C-455	3.29	2.45	16.9	1.9	0.11	0.86	90.0	0.56	1.68	41.3	4.7	0.27	2.10	221	1.38	4.12
Mean	1.506	2.302	14.8	3.0	0.33	0.85	79.8	0.63	1.75	34.3	7.0	0.77	1.94	183	1.45	4.00

The amount of ash, iron, manganese, calcium, magnesium, potassium and phosphorus in the seeds from each of the 22 accessions was determined by analyzing 20 kernels from each lot of seeds. These results and the mean chlorotic value of each accession were compared statistically by means of the regression coefficient (1).

DATA AND DISCUSSION

The mean chlorotic value of the seedlings from the 22 accessions ranged from 1.07 to 3.29 (Table I). The results of the chemical analysis of the kernels are given in Table I.

When the mean chlorotic value is compared with the amounts of iron and manganese in the kernels, the regression coefficients show a highly significant negative relationship between these two constituents and the mean chlorotic value of the accession (Table II). The positive coefficient between the mean chlorotic value and phosphorus

TABLE II—REGRESSION COEFFICIENTS, STANDARD ERRORS AND "t" VALUES OF (1) REGRESSIONS OF MEAN CHLOROTIC VALUE ON IRON, ON MANGANESE, AND ON PHOSPHORUS; (2) PARTIAL REGRESSIONS OF MEAN CHLOROTIC VALUE ON IRON AND MANGANESE, IRON AND PHOSPHORUS, AND MANGANESE AND PHOSPHORUS; AND (3) PARTIAL REGRESSIONS OF MEAN CHLOROTIC VALUE ON IRON, MANGANESE, AND PHOSPHORUS. (FROM CHEMICAL ANALYSIS OF MACADAMIA KERNELS, TABLE I)

Regression of Mean Chlorotic Value on:	Regression Coefficient			Standard Error			"t" Value		
	Fe	Mn	P	Fe	Mn	P	Fe	Mn	P
<i>Per Gram of Dry Tissue</i>									
1 { Fe.....	-0.504	—	—	0.120	—	—	4.192*	—	—
Mn.....	—	-1.589	—	—	0.624	—	—	2.548†	—
P.....	—	—	0.542	—	—	0.298	—	—	1.822
2 { Fe and Mn....	-0.427	-0.877	—	0.125	0.546	—	3.407*	1.607	—
Fe and P.....	-0.640	—	-0.364	0.174	—	0.340	3.669*	—	1.071
Mn and P.....	—	-1.402	0.416	—	0.617	0.276	—	2.272‡	1.506
3 Fe, Mn and P..	-0.546	-0.815	-0.304	0.181	0.552	0.332	3.019*	1.478	0.916
<i>Per Dry Kernel</i>									
1 { Fe.....	-0.177	—	—	0.0450	—	—	3.923*	—	—
Mn.....	—	-0.671	—	—	0.258	—	—	2.598†	—
P.....	—	—	0.116	—	—	0.131	—	—	0.888
2 { Fe and Mn....	-0.146	-0.335	—	0.0498	0.248	—	2.923*	1.349	—
Fe and P.....	-0.176	—	0.00866	0.0480	—	0.107	3.655*	—	0.0811
Mn and P.....	—	-0.661	0.104	—	0.260	0.116	—	2.546†	0.895
3 Fe, Mn and P..	-0.142	-0.340	0.0227	0.0534	0.256	0.105	2.666†	1.330	0.216

*Exceeds 1 per cent point.

†Exceeds 2 per cent point.

‡Exceeds 5 per cent point.

is not significant. These data show that seeds with a relatively small amount of iron grow into seedlings which are chlorotic to a greater degree than those from seeds with a large amount of iron; and seeds with a small amount of manganese also grow into seedlings which are chlorotic to a greater degree than those from seeds with a large amount of manganese.

When the partial regressions of the mean chlorotic value on iron and manganese and on iron and phosphorus are considered, only the nega-

tive coefficient on iron is significant. This denotes that if adjustments to the average iron content are made, there is no significant relationship between the amount of manganese or phosphorus in the seeds and the expression of chlorosis by the seedlings. However, in considering the partial regressions of the mean chlorotic value on manganese and phosphorus, the negative coefficient on manganese is significant. Thus, if iron is eliminated and phosphorus is brought to its average content, seeds with a small amount of manganese produce seedlings which are highly chlorotic.

If the partial regressions of the mean chlorotic value on iron, manganese and phosphorus are considered, only the negative coefficient on iron is significant. These data indicate that when the amounts of manganese and phosphorus in the kernels are held constant, that is, adjusted to their respective averages, seeds with a low iron content grow into seedlings which are highly chlorotic; that there is no significant relationship between the mean chlorotic value and the amount of manganese in the kernels if the iron and phosphorus are adjusted to their averages; and that the relationship between the mean chlorotic value and phosphorus is not significant if the iron and manganese are brought to their averages.

The significance of the statistical determinations is approximately the same if the data from the chemical analysis are calculated either on a percentage basis or on the basis of total amount of each constituent per kernel. Thus, the results may be interpreted as showing that in so far as iron, manganese and phosphorus are concerned, only iron is associated significantly with the expression of chlorosis by macadamia seedlings. Seeds with a low iron content grow into seedlings which are chlorotic to a greater degree than those from seeds with a relatively high iron content.

SUMMARY

Seeds from 22 macadamia accessions were planted in sand cultures and the degree of chlorosis of the seedlings was determined. Certain chemical constituents of the seeds also were estimated. A statistical analysis of these data shows that when iron, manganese and phosphorus are considered, if the manganese and phosphorus contents of the seeds are adjusted to their respective averages, only iron is associated significantly with the expression of chlorosis by macadamia seedlings.

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Additional Studies on Delayed Foliation of Pecan Trees

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IN AN earlier report (1) it was pointed out that a dormant spray of 2-4-dinitro-6-cyclohexylphenol (DNO) both in 1940 and 1941 tended to overcome delayed foliation of pecan trees in the Yuma Valley of Arizona. In the Burkett variety especially, this dormant spray treatment advanced the date of foliation, caused a more uniform breaking of buds over the entire tree, and increased shoot growth and leaf size.

In 1940, the treatment did not increase the number of nuts produced. Apparently this was due to insufficient pollination because the treated trees had produced most of their pistillate blossoms and they had passed stigma receptivity before pollen was available from the same or other varieties in the orchard.

In 1941, nearby Halbert trees were included in the treatment to insure the availability of early pollen. Seven Burkett trees were sprayed with DNO. These gave an increase in yield over 11 check trees of approximately 37 per cent as shown in Table I.

TABLE I—AVERAGE NUMBER OF NUTS PER TREE HARVESTED FROM DNO-TREATED AND CHECK BURKETT TREES IN 1941 (YUMA, ARIZONA)

Location	DNO	Check	Increase
Northeast side of tree	1029	825	204
Southwest side of tree	1234	822	412
Entire tree	2263	1647	616

The data of Table I were found to be significant as determined by the formula:

$$t = \frac{m_1 - m_2}{\sqrt{\frac{\sum D_1^2}{N_1(N_1-1)} + \frac{\sum D_2^2}{N_2(N_2-1)}}} = 3.15$$

where m_1 and m_2 refer to the average number of nuts per tree produced by treated and check trees respectively and where D_1 and D_2 refer to deviation from the mean in the same groups of data.

It was pointed out in an earlier report (1) that in the Yuma Valley where there is a very high percentage of sunshine during the winter months, pecan trees generally yield more heavily on the northeast side of the tree. In Table I the yield of nuts from the two sides of the check trees is shown to be practically the same for the 1941 season. Possibly this more uniform production was the result of greater cloudiness during the winter of 1940-41.

The DNO spray applied to the Halbert trees gave a slightly advanced date of bud break in the spring but there was no increase in yield at harvest time over untreated trees. The Halbert is now known to be a variety which requires relatively little chilling for winter dormancy and the dormancy requirements for it were apparently quite well satisfied during the past winter. Similarly, Burkett trees made no

response to DNO in the Safford Valley where there are many more hours of chilling than at Yuma.

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The Effect of Pruning Upon the Root Distribution of Peach Trees

By E. F. SAVAGE, *Georgia Agricultural Experiment Station, Experiment, Ga.*, and F. F. COWART,¹ *Florida Citrus Experiment Station, Lake Alfred, Fla.*

WITHIN the last decade many studies have been made on the effect of different cultural and fertilizer treatments and of various soils on the root distribution of fruit trees (1, 2, 4, 5, 6), but the effects of pruning on root distribution has received little attention. Chandler (3) found the root system of pruned trees to be smaller relative to the top than that of unpruned trees. His work was concerned primarily with the effect of pruning on the total growth of tops and roots. In the present study, the effect of pruning on the total growth and the distribution of the different sizes of roots through the soil mass has been considered. This report is one phase of a peach root study project which has been carried out at Experiment, Georgia during the past five years, a part of which has been reported on previously by Cowart (4).

MATERIALS AND METHODS

June-budded peach trees of the Mikado variety selected for uniformity of top and root were planted during March 1937. Root pruning at the time of planting consisted only in the removal of broken, twisted, and long, straggly roots. The tops were pruned to a whip and headed at a height of 15 inches. Three or four well-placed shoots were selected for the permanent framework branches as soon as the buds pushed in the spring and all other buds were pinched off as they started growth during the first growing season. All trees were uniformly lightly pruned during the first and second growing seasons. In subsequent pruning the trees were separated into two groups. One group received the conventional dormant season pruning usually given in the peach-growing region of Georgia, which may be regarded as heavy pruning, and the other group of trees were pruned comparatively lightly, consisting of a thinning out of crossing branches, a heading back of excessively tall branches, and a removal of low, hanging shoots. The soil on which these trees were grown belongs to the Cecil series and is classified as a sandy clay loam. It is typical of the soil on which most of the peaches of the Piedmont region of Georgia are grown. The soil profile may be described as follows: 0 to 7 inches grayish-brown, sandy loam; 7 to 30 inches, fairly compact, red clay; 30 to 54 inches, compact, red, brittle clay, containing scattered concretions of mica and quartz; 54 to 144 inches, compact, red, stiff clay, containing considerable and variable quantities of mica and partially disintegrated quartz rock.

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An 8-6-6 (NPK) fertilizer was applied to all trees on a per tree basis as follows: $\frac{1}{4}$ pound March and June 1937; 1 pound March 1938; 3 pounds March 1939; 4 pounds March 1940; 4 pounds March 1941. One-fourth pound of nitrate of soda was applied in June 1938. This fertilizer program kept the trees growing in a normal, vigorous condition. Clean cultivation was practiced throughout the entire experiment. This was accomplished by the use of spiketooth harrow set shallow and sufficient hand hoeing to keep the weeds under control.

In this study, excavations of one tree each of the heavy-pruned group and of the light-pruned group were made during October 1940 and 1941, at the end of four and five growing seasons respectively. The method of excavation as described by Cowart (4) was followed rather closely and briefly consisted in laying off the area around each tree into 1-foot circles with the tree trunk as the center. The soil was dug either in entirety or representative part from each circle in 6-inch increments and the roots separated from the soil to that depth at which no more roots were found. All soil was dug and the roots removed from the 0 to 1, 1 to 2, and 2 to 3 foot circles, and to a depth of 18 inches in the 3 to 4 foot circle. In the subsequent circles beyond the 3 to 4 foot zone, two trenches were dug on the opposite sides of the tree so that each section of soil removed represented a given part of the circle concerned.

The weight of roots found in the two sections of soil were averaged and from this was calculated the weight of roots for the area of the entire circle. After separation from the soil the roots were washed, separated into different sizes, oven dried to constant weight at 65 degrees C, and the dry weight obtained. The roots were separated into the following sizes: less than 2 millimeters, 2 to 5 millimeters, 5 to 10 millimeters, and over 10 millimeters in diameter. That part of the trunk located below ground was considered as root in all cases. The dry weight of the above-ground portion of the trees was obtained by drying to constant weight at 65 degrees C, and included only the weight of the woody parts at the time the trees were dug. The complete growth history, including dry weight of leaves, prunings, and fruit will be presented in a future publication from this Station, but is omitted in this paper for the sake of brevity.

RESULTS

There is a very marked difference in growth made by the heavy and light-pruned trees, as measured by height and spread of tops, circumference of trunk, total dry weight of tops, and total dry weight of roots. These differences are particularly noticeable with the 4-year-old trees, Table I. With the 5-year-old trees, these differences are less marked. The much heavier crops produced by the light-pruned trees are probably beginning to play a more important part in affecting the growth made by the trees as they become older. Table I shows that the above-ground portion of the 5-year-old light-pruned tree is actually smaller than the 4-year-old light-pruned tree in spite of the added year's growth. There is considerable variation in the growth of individual trees receiving the same treatment, but it should also be borne in mind

TABLE I—TOP AND ROOT GROWTH OF HEAVILY AND LIGHTLY PRUNED MIKADO PEACH TREES

Age of Trees	Type Pruning	Height (Feet)	Top Spread (Feet)	Girth (Cm)	Total Dry Weight Tops (Grams)	Root Spread (Feet)	Depth Root Penetration (Feet)	Total Dry Weight Roots (Grams)
4.....	Heavy	9.0	10.0	30.5	13,682	20.0	6.0	9,657
4.....	Light	10.2	13.0	34.3	20,073	26.0	8.0	13,030
5.....	Heavy	11.4	10.9	34.5	18,058	22.0	11.5	12,698
5.....	Light	13.5	11.6	35.4	19,743	26.0	10.0	14,324

TABLE II—DRY WEIGHT IN GRAMS OF ROOTS OF DIFFERENT SIZES OF HEAVILY AND LIGHTLY PRUNED MIKADO PEACH TREES

Age of Trees	Type Pruning	0 to 2 Mm Diameter	2 to 5 Mm Diameter	5 to 10 Mm Diameter	Over 10 Mm Diameter	Total Weight All Sizes
4.....	Heavy	811	1,206	1,325	6,315	9,657
4.....	Light	990	1,290	1,755	8,995	13,030
5.....	Heavy	968	1,012	1,374	9,344	12,698
5.....	Light	1,299	1,088	1,354	10,583	14,324

TABLE III—TOTAL DRY WEIGHT IN GRAMS OF ROOTS LESS THAN 2 MILLIMETERS IN DIAMETER OF HEAVILY AND LIGHTLY PRUNED MIKADO PEACH TREES

Age of Trees	Type Pruning	Distance from Trunk (Feet)												
		0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13
4	Heavy	47.6	139.5	182.3	146.5	62.9	61.1	71.8	55.6	28.4	15.5	—	—	—
4	Light	93.3	149.5	273.5	141.7	55.6	44.7	56.8	34.8	41.9	42.9	20.2	29.9	5.5
5	Heavy	75.0	162.1	171.5	203.5	78.5	82.9	49.5	40.9	36.6	31.7	36.1	—	—
5	Light	86.5	100.1	131.3	109.2	116.4	115.1	136.5	147.6	83.7	68.2	79.9	57.7	66.9

TABLE IV—PERCENTAGES OF ROOTS FOUND WITHIN 18 INCHES OF SOIL SERVICE

	4 Year Trees		5 Year Trees	
	Heavy Pruned (Per Cent)	Light Pruned (Per Cent)	Heavy Pruned (Per Cent)	Light Pruned (Per Cent)
Roots less than 2 millimeters in diameter	75.46	77.59	84.21	61.42
Roots, all sizes	90.83	92.76	97.12	90.53

that the heavy crop of the fifth growing season plus a long period of drought in the spring were not conducive to much top growth. Apparently the degree of pruning has not altered the nature of the root system other than in its total growth and distribution since there is generally about the same proportional reduction in weight of all sizes of roots with the heavy-pruned trees, Table II. Neither is there any indication that the degree of pruning had any effect in causing the roots to be relatively more concentrated in any one particular part of the soil mass occupied by the roots, Tables III and IV. The heavier type of pruning has materially reduced the horizontal extension of the

root system as indicated by the distribution of roots less than 2 millimeters in diameter, Table III. Roots of the light-pruned tree would have access to a much greater reservoir of soil moisture and nutrients. It is of interest to note that over 90 per cent of the total tree roots and about 75 per cent of the roots less than 2 millimeters in diameter are located within 18 inches of the soil surface with trees of these ages, Table IV.

DISCUSSION AND CONCLUSIONS

The greater amount of dry matter in the above-ground portion of light-pruned trees, of the ages considered, is also reflected in the much greater total growth and extent of distribution of roots. It is believed that less severe pruning with young trees than is generally practiced in the peach-growing region of Georgia would be of great benefit in obtaining trees of profitable bearing size at an earlier age. That the pruning of young peach trees has been too severe in the past is conceded by many growers and research workers alike. The evidence presented in this paper substantiates the above view and indicates that heavy pruning during the early life of the trees might also be reflected in smaller yields, even some time after the pruning is moderated.

A high percentage of the roots of peach trees, grown under the conditions described in this paper, are located in the upper 18 inches of soil. With younger trees, an even greater percentage of the total tree roots are located within this soil depth (4). This might be an explanation of the detrimental effect of some cover crops on the peach, particularly during the early life of the trees. It may also explain the reduced growth of trees on land which is even slightly eroded. Roots were found to penetrate the red, compact clay subsoil to a depth of about 10 feet with 5-year-old trees. Even though the number of roots in these lower depths is small, they are undoubtedly of great value during periods of drouth. The distribution of roots with these ages of trees and the density of roots within a given soil area indicate rather clearly the place in which fertilizer should be applied for most efficient use.

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Effects of Pruning Old Washington Navel Orange Trees¹

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PRUNING of orange trees in the southwest during recent years has usually been confined to removal of dead twigs. Occasionally the pruning includes the removal of limbs carrying green leaves, with such objectives as exposing more of the inside of the tree to direct sunlight, removal of weak growths, or invigoration of weakly growing trees. There has been almost no experimental evidence upon the effects of such pruning.

In 1914 young (12-year-old) Washington Navel orange trees in the Corona locality were pruned with different degrees of severity, with the result that the yields in the two following years were reduced about in proportion to the amount of foliage removed (2). Size or commercial grade of fruit was not appreciably affected. The lack of experimental evidence upon the effects of pruning of old trees suggested the initiation of additional studies in 1939.

METHODS

The trees selected were old, lacking in vigor and low in yield of fruit; and were located near Highgrove of the Riverside locality. Those trees in Series A, planted in 1902, were in Holland loam, and for several years had received annually in winter or early summer 20 pounds per tree of an 8-8-4 commercial fertilizer, with a summer or early fall application of organic material at the rate of 5 tons per acre. The $2\frac{1}{4}$ to $2\frac{1}{2}$ pounds of nitrogen thus applied were, however, largely distributed in the irrigated middles. The light green foliage color suggested that much of the applied nitrogen was lost in leaching. The trees in Series B, planted in 1895, were in Ramona loam, had received during the past few years 1 to $1\frac{1}{2}$ pounds of nitrogen per tree from ammonium sulphate or liquid ammonia, and had improved in vegetative vigor during 1939 and 1940. These trees were in poorer condition than those in Series A and had been a problem to the owner for several years.

No pruning had been given these trees for several years prior to 1939, when all pruning was done. In both Series A and Series B there were five treatments: (a) not pruned, (b) early pruned — medium, (c) early pruned — heavy, (d) late pruned — medium, and (e) late pruned — heavy. "Early" pruning was in late March or early April after elongation of the spring flush of shoot growth had ceased, but before many blossoms had appeared. Full bloom was from April 20 to 30. "Late" pruning was in June, before the completion of drop of small fruits. "Medium" pruning involved removal of an estimated 15 per cent of the leaf area; "heavy" pruning, 25 per cent. Pruning consisted in thinning out limbs up to $\frac{3}{4}$ inch in diameter throughout

¹The facilities for this study were made possible by the cooperation of the L. V. W. Brown Estate and of its manager, D. S. Bell.

the tree. All pruning in both series was done by the same man. Individual trees receiving each treatment were selected at random in five rows in Series A and in four rows in Series B.

Individual tree yields were recorded in field boxes (capacity approximately 45 pounds), with fractions of a box estimated in tenths. Trees in Series A were picked in January or February, trees in Series B in March or April. With the crops from bloom in 1939, 1940, and 1941 respectively, all fruits in each box were counted, to give the total number of fruits from each tree. For the crop records taken before the pruning was performed, fruits were counted in only one box in 20 or 30. Separate counts were made of drops, which amounted to about 4 to 8 per cent of the yield per tree. Statistical significance of data was determined by analysis of variance as outlined by Snedecor (3).

RESULTS

Yields.—The average yields per tree, both before and after the pruning, are given in Table I. In Series A, pruning in 1939, either

TABLE I.—EFFECT OF TIME AND SEVERITY OF PRUNING WASHINGTON NAVEL ORANGE TREES IN 1939 UPON AVERAGE YIELDS DURING THE THREE FOLLOWING YEARS

Treatment	No. of Trees	Average Yields Per Tree (Box)†				
		Before Pruning		After Pruning		
		1937	1938	1939	1940	1941
<i>Series A</i>						
Not pruned.....	9	5.9	7.7	7.6	6.4	6.6
Early pruned—medium...	10	6.4	7.8	6.2§	6.3	7.2
Early pruned—heavy....	10	6.2	7.9	5.5§	6.0	7.4
Late pruned—medium....	9	5.7	6.9	5.8§	5.7	6.2
Late pruned—heavy.....	10	6.2	7.4	5.1§	5.2*	6.5
<i>Series B‡</i>						
Not pruned.....	18	—	1.8	3.6	4.0	4.1
Early pruned—medium...	18	—	2.0	3.6	4.3	4.8
Early pruned—heavy....	17	—	2.0	3.2	3.5	4.5
Late pruned—medium....	17	—	1.8	2.6§	4.0	4.4
Late pruned—heavy.....	17	—	2.1	2.3§	4.1	4.6

†Yields are from the bloom of years shown.

‡Odds 99:1 for significance, in comparison with no pruning.

*Odds 19:1 for significance, in comparison with no pruning.

‡The yield figures in Series B for 1938 are averages of estimated yields for each tree before picking.

before or after full bloom, seemed to reduce the yield of fruit set in 1939 from 19 to 33 per cent below that of the unpruned trees, with odds for significance of at least 99:1. With no additional pruning in 1940, the yield from the fruit set in 1940 was not significantly less from the pruned trees than from the unpruned trees, except in the case of "late pruned—heavy". The yield from the fruit set in 1941, two years after the pruning, was about the same on pruned as on unpruned trees. Although the data for 1941 show an 8 to 14 per cent greater yield for early pruning (in 1939) than for no pruning, the odds for significance are less than 19:1.

In Series B the early pruning (before full bloom) in 1939 did not significantly reduce yield of the crop set in 1939, as did occur in Series A. Late pruning in 1939 seemed to reduce the 1939 crop, but did not significantly affect the yields of fruit set in 1940 or 1941.

Number of Fruits per Tree:—The average numbers of fruits set per tree each year, based upon counts at picking time of picked fruit and of drops, are given in Table II. In Series A the pruning in 1939 seemed to reduce the number of fruits set per tree below the number

TABLE II—EFFECT OF TIME AND SEVERITY OF PRUNING WASHINGTON NAVAL ORANGE TREES UPON NUMBER OF FRUITS PER TREE (PRUNING DONE IN 1939)

Treatment	Average Number of Fruits Per Tree for Year Crop was Set				
	Before Pruning		After Pruning		
	1937	1938	1939	1940	1941
<i>Series A</i>					
Not pruned.....	810	1,270	968	676	813
Early pruned—medium.....	877	1,291	709†	691	911
Early pruned—heavy.....	852	1,305	635†	642	925
Late pruned—medium.....	777	1,136	692†	585	827
Late pruned—heavy.....	849	1,225	633†	530*	857
<i>Series B</i>					
Not pruned.....	.....	290†	562	700	557
Early pruned—medium.....	.....	320†	553	739	648*
Early pruned—heavy.....	.....	310†	490	621	603
Late pruned—medium.....	.....	280†	408†	713	590
Late pruned—heavy.....	.....	330†	355†	723	628*

†Odds 99:1 for significance, in comparison with no pruning.

*Odds 19:1 for significance, in comparison with no pruning.

†Estimated number of fruits, based upon estimated yields for each tree before picking in April 1939 and upon counts of number fruits in 13 field boxes.

of fruits set on the unpruned trees. The reduction in number of fruits per tree was 27 to 28 per cent with medium pruning, and 34 to 35 per cent with heavy pruning. These reductions in number of fruits are proportionately greater than the estimated reductions in leaves and twigs incident to pruning. The data show no indication that the time of pruning influenced the extent of reduction in set of fruit in 1939.

In 1940, the year after the pruning, there were 14 to 22 per cent fewer fruits for late pruned (in 1939) than for the unpruned trees; but only in the case of the "heavy" pruning was the difference significant by odds as great as 19:1. In 1941, two years after the pruning, the late pruned trees had about the same number of fruits as the unpruned. That year the early pruned (in 1939) trees had from 12 to 14 per cent more fruits than the unpruned, but this difference was not significant by odds of 19:1 or more.

In Series B the trees with late, medium pruning, in comparison with trees with no pruning, produced 27 per cent less fruits in 1939, while the trees with late, heavy, pruning produced 37 per cent less, with significance by odds of at least 99:1. This agrees with the results for late pruning in Series A. However, with the early pruned trees, medium pruning did not seem to appreciably affect the number of fruits

per tree and heavy pruning showed a reduction in number of fruits of only 13 per cent, with that difference not significant. None of the differences between treatments in 1940 or 1941 are significant by odds of 99:1 or more. The apparent significance, by odds of 19:1, of the greater yield in 1941 with early medium, and late heavy pruning than with no pruning might have been the result of the same factor that was responsible for the estimated larger fruit production by these trees before pruning.

Size of Fruit:—The only available data indicating fruit size are average number of fruits per box. The reciprocals of the average number of fruits per box, which express fruit sizes as fractions of a box, are given in Table III. In general, the effect of pruning upon fruit size was either negligible or very small.

TABLE III—EFFECT OF TIME AND SEVERITY OF PRUNING OF WASHINGTON NAVAL ORANGE UPON AVERAGE SIZE OF FRUIT

Treatment	Average Size Per Fruit, in Fractions of a Field Box Each Year After Pruning		
	1939	1940	1941
<i>Series A</i>			
Not pruned.....	0.0079	0.0094	0.0082
Early pruned—medium.....	0.0088*	0.0092	0.0079
Early pruned—heavy.....	0.0086*	0.0094	0.0080
Late pruned—medium.....	0.0083	0.0097	0.0075
Late pruned—heavy.....	0.0082	0.0099	0.0075
<i>Series B</i>			
Not pruned.....*	0.0069	0.0075	0.0074
Early pruned—medium.....	0.0069	0.0077	0.0074
Early pruned—heavy.....	0.0070	0.0080	0.0074
Late pruned—medium.....	0.0068	0.0074	0.0074
Late pruned—heavy.....	0.0069	0.0075	0.0073

*Odds 19:1 for significance, in comparison with no pruning.

In Series B the pruning 1939 apparently had no appreciable effect upon size of fruit in 1939, 1940 or 1941. In Series A, the early pruned trees had from 9 to 11 per cent larger fruit in 1939 than the unpruned, with odds for significance of at least 19:1; whereas, the late pruned trees had only 4 to 5 per cent larger fruit than the unpruned, and this difference was not statistically significant.

Quality of Fruit:—In Series A, fruits of the 1939 crop were collected from certain trees prior to picking, for measurement of peel, rag, juice soluble solids and titratable acidity. For each tree one 10-fruit sample was taken from each of four locations, inside and outside of both north and south halves of the tree. On any one day fruits from both an “unpruned” and a “heavy pruned—early” tree were obtained, and measurements made on individual fruits. Of the total fresh weight per fruit the peel represented 29 per cent, rag 29 per cent, and juice 42 per cent. Soluble solids were about 13.3 per cent and titratable acidity about .96 per cent. A slightly greater peel thickness and a slightly lower titratable acidity for fruits from pruned trees were probably related to the slightly larger size of the fruit from the pruned trees. In the other physical characteristics, the fruits from

the pruned trees showed little or no difference from those from the unpruned. In no case was fruit from any of the pruned trees in either series visibly different in appearance or flavor from that from unpruned trees.

DISCUSSION

The results of pruning these old Washington Navel orange trees, lacking in vigor, are essentially the same as the earlier results (2) with young, vigorous trees. The fact that this pruning of old trees did not consistently reduce the yields the second year after the pruning, whereas the pruning of young trees in 1914 did reduce the yield for two years, was probably because of less severe pruning than in 1914.

In Series A the reduction in number of fruits set per tree the year of the pruning was apparently the result of the removal of flowers or young fruits in pruning, without stimulation in the set of fruit on the remaining branches. Since the reduction in number of fruits per tree by pruning was proportionately greater than the estimated reduction in leaves and twigs during the pruning, the pruning may have resulted in a slightly lower percentage of flowers setting fruit or a greater percentage drop of small fruits, than for the unpruned trees. In Series B the early pruning (just before full bloom) did not reduce the number of fruits per tree, as it had in Series A. It is possible that because the trees in Series B seemed to be responding to nitrogen applications with increased set of fruit (as indicated by progressively more fruits per tree each year from 1938 to 1940, inclusive), the effect of early pruning upon percentage of remaining flowers setting fruit may have been different from the effect of early pruning upon the trees in Series A.

Cameron and Hodgson (1) found very rapid regeneration of their "light" pruned citrus trees (their "light" pruning was more severe than the heavy pruning reported here), with the weight of the leaves produced the first year equal to the weight of the leaves before pruning. Such regeneration of leaf area following pruning was not apparent by casual observation in either Series A or B. Although pruned trees developed a few vigorous shoots in the center, no general flush of new growth occurred on either pruned or unpruned trees in 1939 after April. Thus the fact that in 1940, the second season after the pruning, the pruned trees in most treatments set about as many fruits as the unpruned seems particularly significant. Several explanations seem plausible:

1. The removal of leaves by pruning exposed, during the summer of 1939, hitherto shaded leaves or buds, with the result that previously inactive buds produced flowers and fruits in 1940.

2. Reducing the number of leaves and buds by pruning increased the supply of water, mineral nutrients, or carbohydrates to remaining buds, with the result (a) that the 1940 flowers from these buds set fruit more readily, (b) that a smaller percentage of the fruits that set dropped in May or June, or (c) more flowers and fruits were produced on each new growth in 1940.

3. The regeneration of leaves, as observed by Cameron and Hodgson, occurred on the pruned trees in 1939 to the extent that the leaf

area and flower-bud development was about as great by the spring of 1940 as for unpruned trees.

The indications in Series A that late pruning reduced the number of fruits in 1940 below that of early pruned trees, and in Series B that early pruning did not reduce the number of fruits in 1939 as much as did late pruning, suggest that pruning before full bloom reduces fruiting less than pruning after full bloom.

The reason for the slightly larger fruits in 1939 for early pruning than for no pruning in Series A is not clear. Presumably the apparently greater reduction in number of fruits per tree in 1939 than the reduction in leaf area by the early pruning resulted in a greater leaf area per fruit in 1939 for the pruned than for the unpruned trees.

SUMMARY

Pruning old Washington Navel orange trees, low in vigor, tended to reduce the number of fruits per tree the year of the pruning, with little or no increase in the size of the fruit. The second year after the pruning the number of fruits per tree were, in most cases, about the same as with no pruning. There was some indication that pruning before full bloom reduced the number of fruits per tree, either the first or the second year after the pruning, less than pruning after full bloom.

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Some Factors Affecting Rate of Date Leaf Elongation¹

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INDICATIONS (8, 9) that rate of leaf elongation might be used as an index of water deficits in the date palm due to deficiency of soil moisture led to a study during 1938 to 1942 of factors affecting leaf elongation. This study included the effects of age of leaf, season, relative humidity, and maximum temperature of the air, leaf area reduction, and leaf/bunch ratio. Mason (4, 5, 6) had already studied the effects of minimum winter temperatures, mean daily temperatures, and light.

METHOD OF MEASURING LEAF ELONGATION

As the leaf emerges from the crown of the palm (see Fig. 1), it moves upward until, as its length increases, the weight of the distal portion causes it to lean to one side. The extent of this vertical movement, or elongation, was determined by attaching the upper end of a flexible wire to the rachis, extending the wire down the trunk, and then measuring periodically the change in distance between a marker (nail) on the lower end of the wire and a fixed point on the trunk. For a newly emerged leaf, this method could not be used until the distal end of the rachis



FIG. 1. Leaves emerging from the crown of a Deglet Noor palm, with a white cord showing the method of attaching wire to the rachis (mid-rib) of a newly emerged leaf. Note: Two leaves were cut off at the fibre line to expose newly emerged leaf.

¹These results were obtained in the cooperative research program by the Bureau of Plant Industry, United States Department of Agriculture and the Office of Indian Affairs, United States Department of the Interior.

The writers appreciate the assistance of Roland R. Hutchings in measuring leaf elongation in 1941.

had reached about 30 centimeters above the upper edge of the fiber around the trunk. The age of leaf was measured in days after the wire was thus attached. When the leaf had elongated 80 to 100 centimeters, the point of attachment of the wire was moved to a lower position on the rachis. All growth seems to occur inside the crown, for no elongation of the emerged portion of the leaf was detected.

The leaves emerge one at a time, and not in groups of three as suggested by Albert and Hilgeman (1). Each succeeding leaf appears between 137 and 138 degrees around the trunk and at a slightly higher level. This sequence of emergence is illustrated by the numbered cross-section in Fig. 2. An average angle of approximately 137.6 degrees

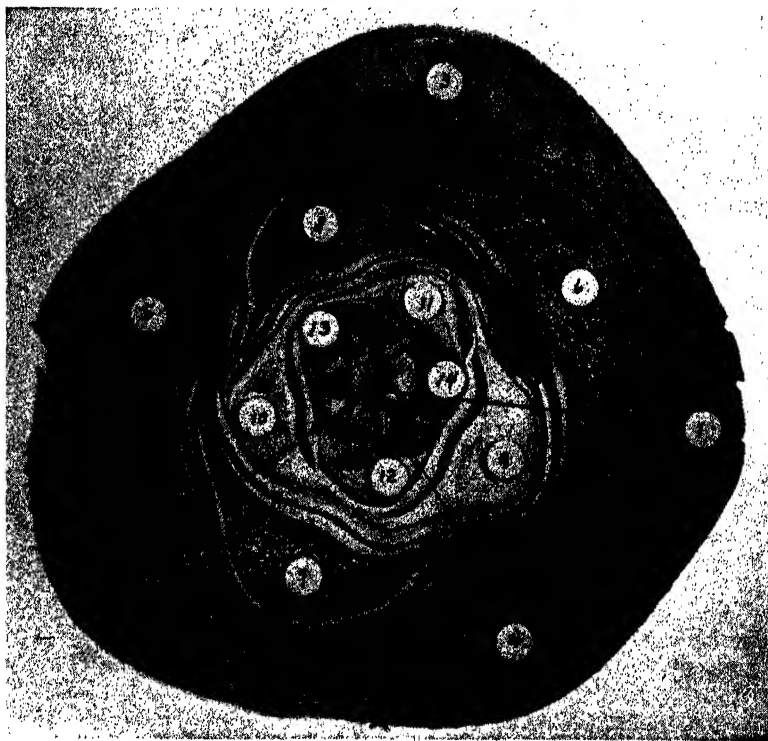


FIG. 2. Cross-section of a date palm (variety Hayany), just above the single terminal bud, or phylophore. Number 1 is the oldest leaf, number 2 next, etc. Note the inflorescences in the axils of some of the leaves. (About one-half natural size.)

must be traversed in passing from the median insertion point of leaf No. 1 to that of leaf No. 2, from No. 2 to 3, and so on. To arrive at a leaf almost directly above or below any reference leaf (number 0), by counting leaves in sequence, 34 leaves have to be counted and the axis has to be encircled 13 times. Thus the phyllotaxy would be ex-

pressed as 13/34. This is an approximation because of the difficulty in judging whether a leaf is directly above or below another in its point of insertion. The complex pattern of spirals of leaves thus formed about the trunk is quite consistent and definite in arrangement, and has been described for the Deglet Noor variety by Mathez and Bliss (7). In *Phoenix canariensis* the same pattern of spirals was observed by Bradley (3) to be characteristic of only one period in the growth of the palm.

RESULTS

Age of Leaf.—By continuing the measurement of consecutive leaves until elongation had about ceased, the average rate of leaf elongation for short periods was determined for each leaf appearing during a year on three palms of the Deglet Noor variety. The results with 10 consecutively emerging leaves, Nos. 8 to 17, on palm 7-7-6 are given in Table 1. For all leaves but No. 14 the measurements were started

TABLE 1.—AVERAGE DAILY RATES OF ELONGATION FOR CONSECUTIVELY EMERGING LEAVES DURING SHORT PERIODS FOLLOWING TIME WHEN THE DISTAL END OF RACHIS REACHED ABOUT 30 CENTIMETERS ABOVE FIBER (DEGLET NOOR 7-7-6, UNITED STATES DATE GARDEN, 1941)

Approximate Period for Which Rate was Calculated	Rate of Leaf Elongation for Different Leaves on Same Palm (Cm/Day)										Standard* Deviation Single (Cm/Day)
	8	9	10	11	12	13	14	15	16	17	
June 18-23.....	3.9	—	—	—	—	—	—	—	—	—	—
June 23-27.....	4.5	—	—	—	—	—	—	—	—	—	—
June 27-July 2....	4.4	4.1	—	—	—	—	—	—	—	—	—
July 2-9.....	4.2	4.2	—	—	—	—	—	—	—	—	—
July 9-14.....	4.3	4.3	4.3	4.2	—	—	—	—	—	—	—
July 14-21.....	4.4	4.4	4.4	4.4	—	—	—	—	—	—	—
July 21-28.....	4.7	4.7	4.6	4.7	4.7	—	—	—	—	—	±0.05
July 28-Aug. 2....	4.5	4.3	4.3	4.4	4.2	4.4	—	—	—	—	±0.07
Aug 2-8.....	4.7	4.6	4.6	4.7	4.7	4.6	—	—	—	—	±0.06
Aug 8-12.....	5.3	4.9	5.0	5.0	5.0	5.0	—	5.0	—	—	±0.13
Aug 12-18.....	4.6	4.6	4.4	4.7	4.5	4.3	4.3	4.4	—	—	±0.15
Aug 18-25.....	3.5	3.6	4.3	3.9	4.1	4.0	4.2	4.1	3.9	4.2	±0.15
Aug 25-Sep 1.....	2.0	2.8	4.4	4.1	4.0	4.1	4.1	4.1	4.2	4.2	±0.12
Sep 1-5.....	1.5	2.0	4.3	4.6	4.6	4.1	4.4	4.4	4.5	4.4	±0.16
Sep 5-15.....	0.9	1.4	2.4	3.8	4.6	4.4	4.3	4.4	4.5	4.3	±0.12
Sep 15-22.....	0.4	0.7	1.2	1.9	3.2	4.1	4.2	4.3	4.3	4.3	—
Sep 22-Oct 2.....	0.1	0.4	1.0	1.1	1.7	2.9	4.0	4.4	4.2	4.3	—
Oct 2-14.....	0.1	0.2	-0.02	0.4	0.8	1.4	2.0	3.6	4.4	4.4	—
Oct 14-23.....	0.01	0.00	0.1	0.2	0.3	0.9	1.0	1.7	2.9	4.3	—
Oct 23-Nov 3.....	—	—	0.0	0.1	0.1	0.2	0.3	0.6	1.2	1.9	—
Nov 3-10.....	—	—	—	0.1	0.1	0.2	0.4	0.6	1.0	1.5	—
Nov 10-19.....	—	—	—	-0.04	0.1	0.1	0.1	0.3	0.5	0.9	—
Nov 19-21.....	—	—	—	0.1	0.1	0.1	0.2	0.1	0.3	0.5	—
Nov 21-Dec 1.....	—	—	—	—	—	0.0	0.1	0.1	0.2	0.3	—
Dec 1-15.....	—	—	—	—	—	—	0.0	0.1	0.1	0.2	—
Dec 15-30.....	—	—	—	—	—	—	—	0.0	0.05	0.1	—
Date of Wiring (A)	June 18	June 27	July 9	July 9	July 21	July 28	Aug 12	Aug 8	Aug 22	Aug 22	
End of period of maximum rate of elongation (B)	Aug 18	Aug 18	Sep 5	Sep 5	Sep 15	Sep 22	Oct 2	Oct 2	Oct 14	Oct 23	
Number of days from A to B	61	52	58	58	56	56	51	55	53	62	

$$\text{*Standard Deviation} = \sqrt{\frac{\sum D^2}{n-1}}$$

when the distal end of the rachis was about 30 centimeters above the fibre. The rate of elongation varied from period to period; but during any one period each leaf grew at about the same rate, the standard error of a single leaf being not more than ± 0.16 centimeter per day. At the end of about 51 to 62 days after the distal end of the rachis was 30 centimeters above the fibre, however, the rate of elongation of a leaf became very much less than that of younger leaves, and had ceased 50 to 60 days later.

Similar data for palm 7-7-4 showed that, after the distal end of the rachis was about 30 centimeters above the fibre, the leaves elongated from 54 to 64 days before showing the sudden decline in rate. In the case of palm 7-7-3, with a generally lower rate of leaf elongation apparently due to soil moisture deficiency, the leaves elongated from 55 to 79 days before showing the sudden decline in rate.

To extend the data presented in Table I to include each consecutive leaf as it started to decline in growth rate, the rates of leaf elongation from just before until several weeks after the decline started are presented in Fig. 3.

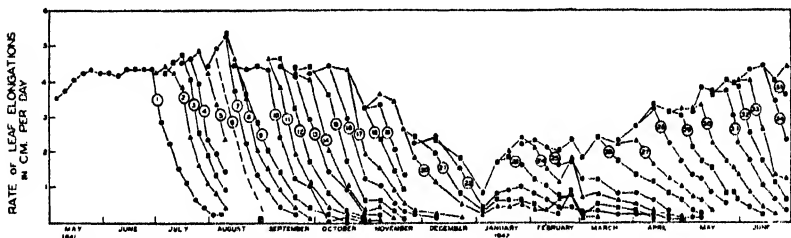


FIG. 3. Rates of elongation of leaves, in consecutive order of emergence, for the period from just before until several weeks after their growth rate decreased below that of younger leaves.

Leaf No. 6 was inadvertently omitted in the wiring, but was subsequently found in the location on the palm midway between leaves Nos. 5 and 7.

Leaves showing the decline in rate in July, August, September or October had about stopped elongating at the end of 40 to 60 days; but leaves that did not begin the decline until November, December, January or February continued at a reduced rate for 90 to 120 days. As the rate of leaf elongation reached values above 2.0 centimeters per day after the middle of March, leaf elongation again stopped at the end of 40 to 60 days after the decline in rate started.

Season:—From the data used in preparing Fig. 3, it was possible to determine when the decline in rate for each leaf first began to occur. These rates before decline were averaged for each period between measurements from April 2, 1941 to May 12, 1942 and are presented in Fig. 4, with the rate for each period plotted at the mid-point of that period.

The rate of elongation was usually above 4.0 centimeters per day from May 15 to October 18. The lower rates before and after this 5-month period were probably due directly, or indirectly, to sub-

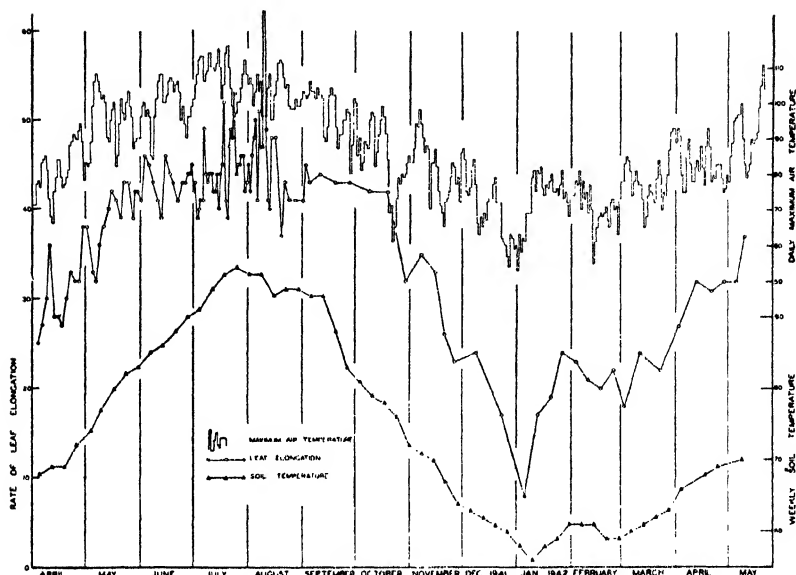


FIG. 4. Rate of leaf elongation in millimeters per day during a 14-month period, in comparison with daily maximum air temperature and weekly average soil temperature at the 30-inch depth.

optimal temperatures, as pointed out by Mason (5). Since Mason (5) showed that the temperature of the center of the trunk below the apex seemed to follow, within a few degrees, the temperature of the soil at a depth of 2 feet, the close parallelism in Fig. 4 between rate of leaf elongation and soil temperature suggests that soil temperature may be an important factor influencing the rate of leaf elongation.

Soil Moisture:—The results relating leaf elongation to soil moisture and water deficits in the palm will be reported elsewhere. However, in Fig. 4 the rate of leaf elongation apparently was affected by soil moisture deficiency during May and June, and once in late August, 1941. The rapid increase in rate of elongation following temporary minima in rate on May 6, May 20, June 17 and August 19, respectively, coincided with irrigation; indicating that just before each of those irrigations soil moisture deficiency was limiting leaf growth. The other temporary reductions in rate of elongation were in many cases undoubtedly the result of water deficits in the palm during periods of high transpiration; but the evidence from adjacent irrigation plots indicates that soil moisture was not the limiting factor.

Relative Humidity and Temperature:—In an attempt to explain summer fluctuations in rate not related to soil moisture, the rate was determined daily from June 28 to August 14. Failure to measure accurately the evaporating power of the air left only daily maximum and minimum air temperatures and relative humidity at 8:00 a.m. for use in evaluating meteorological conditions. These data are shown in Fig. 5. The average rate of elongation for this period was 4.5 centi-

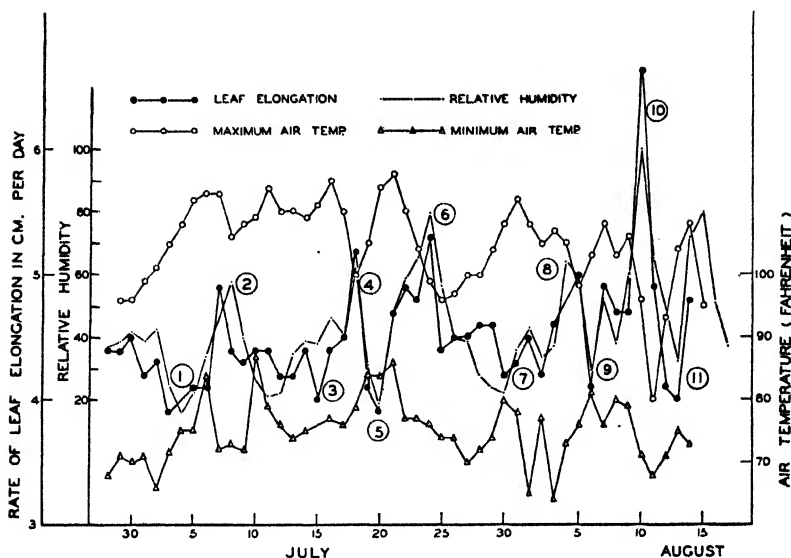


FIG. 5. Daily rate of leaf elongation, in comparison with daily maximum and minimum air temperatures and with relative humidity at 8:00 a.m. Rate of elongation is plotted for the morning following the night during which the elongation occurred; and maximum air temperature for one day is plotted on the day following to coincide with the elongation which it could affect.

meters per day. On a number of days the rate per day was 0.5 centimeter or more above or below the average rate. These fluctuations were, in a general way, directly proportional to the relative humidity percentage at 8:00 a.m. of the morning following the night in which the leaf elongation occurred. The relative humidity values of 80 per cent at 8:00 a.m. on July 24 (maximum No. 6) and of 100 per cent on August 10 (maximum No. 10) were associated with rain; and those of 55 and 59 per cent on July 7 and 8 (maximum No. 2), of 62 per cent on July 18 (maximum No. 4) and of 64 per cent on August 4 (maximum No. 8) were associated with storms to the south or south-east, which apparently moved in moist air. These relative humidity values of 55 per cent or more at 8:00 a.m. were higher than normal, and seemed largely responsible for the rate of leaf elongation maxima Nos. 2, 4, 6, 8, and 10. Other variations in relative humidity seemed to be the result of temperature variations, which in all probability directly influenced leaf elongation. The minima in rate of leaf elongation designated as Nos. 3, 5, and 7 were associated with maximum air temperatures (during the afternoon preceding the night when elongation occurred) of 108 degrees or more. The influence of such high temperatures may have been either (a) to reduce photosynthesis or increase respiration to the extent that carbohydrate supply to the growing region of leaf was reduced, or more probably (b) to increase transpiration to the extent that dehydration in the growing region reduced cell enlargement the following night.

Leaf Removal.—Since in commercial date growing a large number of the lowest (oldest) green leaves are frequently removed in mid-summer, the effect of leaf removal was studied in 1938, using six Deglet Noor palms growing with a slight deficiency of soil moisture. The rate of leaf elongation was measured from June 21 to July 21; half the leaves were removed on July 21; and then leaf elongation was measured for another month. In removing leaves, every other leaf was cut off, and also half of the fruit bunches. This left the same leaf/bunch ratio after leaf removal as before. The results, summarized in Table II, show that removal of half of the leaf area (and also half the crop of

TABLE II—EFFECT OF REMOVING HALF OF THE LEAVES (ALSO HALF THE CROP OF FRUIT) UPON RATE OF LEAF ELONGATION (DEGLET NOOR, 1938)

Treatment	Palm Number	Average Rate of Leaf Elongation for Each of Two Periods	
		June 21 to July 21 (Cm/Day)	July 21 to August 26 (Cm/Day)
Control	3 11	3.74	3.30
	3-13	3.59	3.31
	3 17	3.20	2.70
Half of leaves and half of crop removed on July 21	3 10	3.51	3.53
	3 15	3.04	3.70
	3 18	3.20	3.24

fruit) resulted in about 13 per cent higher rate of elongation than on palms where no leaves were removed. The reduction in leaf area may have reduced total transpiration to the extent that the water supply to the growing leaf bases or to the remaining leaf area was increased, as found by Aldrich and Work (2) with pears. However, since the removal of nearly 50 per cent of the leaf area increased the rate of leaf elongation only 13 per cent, the usual commercial practice of removing only 20 to 25 per cent of the leaf area would not be expected to materially affect elongation.

Leaf/Bunch Ratio.—In commercial practice the usual number of moderately thinned bunches left per palm allows from 6 to 10 leaves for each bunch. To determine whether different leaf/bunch ratios would affect rate of leaf elongation a block of 40 palms were used in 1939. In the spring leaves were cut off to have 30 leaves per palm remaining; and then the desired leaf/bunch ratios were obtained by bunch removal in June. Leaves appearing subsequently were disregarded. The results, summarized in Table III, indicate that palms

TABLE III—EFFECT OF LEAF/BUNCH RATIO UPON RATE OF LEAF ELONGATION (DEGLET NOOR, 1939)

Treatment (Number of Leaves Per Bunch)	No. of Palms	Mean Daily Rate of Leaf Elongation for Period June 13 to October 19 (Cm/Day)
15	8	4.83
10	8	4.78
7.5	8	4.47
6	8	4.36
3	8	3.81

Least difference for significance; 5 per cent = 0.483; 1 per cent = 0.652.

with fewer leaves per bunch had lower rates of leaf elongation than palms with more leaves per bunch, but not all of the differences are statistically significant. Leaf elongation with only three leaves per bunch was from 15 to 21 per cent less than with 7.5, 10 or 15 leaves per bunch, with odds for significance greater than 99:1.

DISCUSSION

The very small differences in rate of elongation between recently emerged leaves on the same palm show that the rate of leaf growth of a specific palm can be determined within about 0.3 centimeter per day by the measurement of one leaf only. However, the measurement of two leaves per palm is expedient because one wire may become tangled by pinnae or spines. In practice a leaf is usually measured for about 3 weeks after its emergence without moving the point of attachment of the wire. With a more extended period the wire is usually fouled by the pinnae or spines on other leaves. At the end of 3 weeks, the wire can be transferred to a younger leaf, because in summer a new leaf emerges every 6 to 10 days. Since at least 50 days must elapse between the time a newly emerged leaf can be wired and the time when the decline in growth rate begins, there is little danger of obtaining low rate values as a result of advanced age of leaf if the above procedure is followed.

The pronounced effects of air or soil temperatures in limiting the rate of leaf elongation from about October 15 to June 1, makes the leaf growth less well adapted as an index of water deficits in the palm during the cooler months than during the June 1 to October 15 period. The relatively large fluctuations in rate of leaf elongation from day to day in summer are usually of only 1 to 3 days duration (Fig. 5), but average rates for 6- or 7-day periods smooth out many of the fluctuations attributable to variations in transpiration or temperature.

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Fruit Shrivel of the Halawy Date in Relation to Amount and Method of Bunch Thinning¹

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ALTHOUGH cutting back strands to reduce the number of date fruits per bunch (bunch thinning) has been generally satisfactory with the Deglet Noor variety (2), it has appeared to increase the amount of shrivel of fruit of the Halawy variety. Since Halawy is grown commercially and is a soft date more subject to shrivel than some other varieties, the relation of fruit shrivel in this variety to amount and method of bunch thinning was studied in 1941.

EXPERIMENTAL PROCEDURE

At the Martinez Research Station in Coachella Valley, California, 32 palms, 6 to 8 years of age, were selected for the experiment. All inflorescences were pollinated with the same pollen, and, about 10 days after the pollination one-fifth of the flowers or young fruits were thinned from the center by removing entire strands. At the same time, unless otherwise noted, the special thinning treatments listed below were applied to one bunch on each of the 32 palms. The bunches used were all pollinated within a period of two to three weeks from the latter part of March to the middle of April, and within this period the time of pollination did not appear to affect the results. The treatments were as follows:

1. Two bunches per palm without additional thinning were left as checks (Fig. 1, A).
2. One-half of the remaining flowers or young fruits were removed from one bunch per palm *by cutting out entire strands* (Fig. 1, B, total reduction 60 per cent).
3. One-half of the remaining flowers or young fruits were removed from one bunch per palm *by cutting back all strands* (Fig. 1, C, total reduction 60 per cent).
4. Seven-eighths of the remaining flowers or young fruits were removed from one bunch per palm by cutting back strands (Fig. 1, D, total reduction 90 per cent).
5. Same as 3, except that beginning August 12 the bunch was enclosed in a bag made of a paraffined muslin called "Vito-fabric".
6. Same as 3, but thinning delayed from March until June 6.

On June 14 half of the 32 palms were adjusted by leaf removal to a low leaf/bunch ratio and the other half left with the maximum number of green leaves. Because of variation in age and size of palms they were further divided into two groups according to the number of

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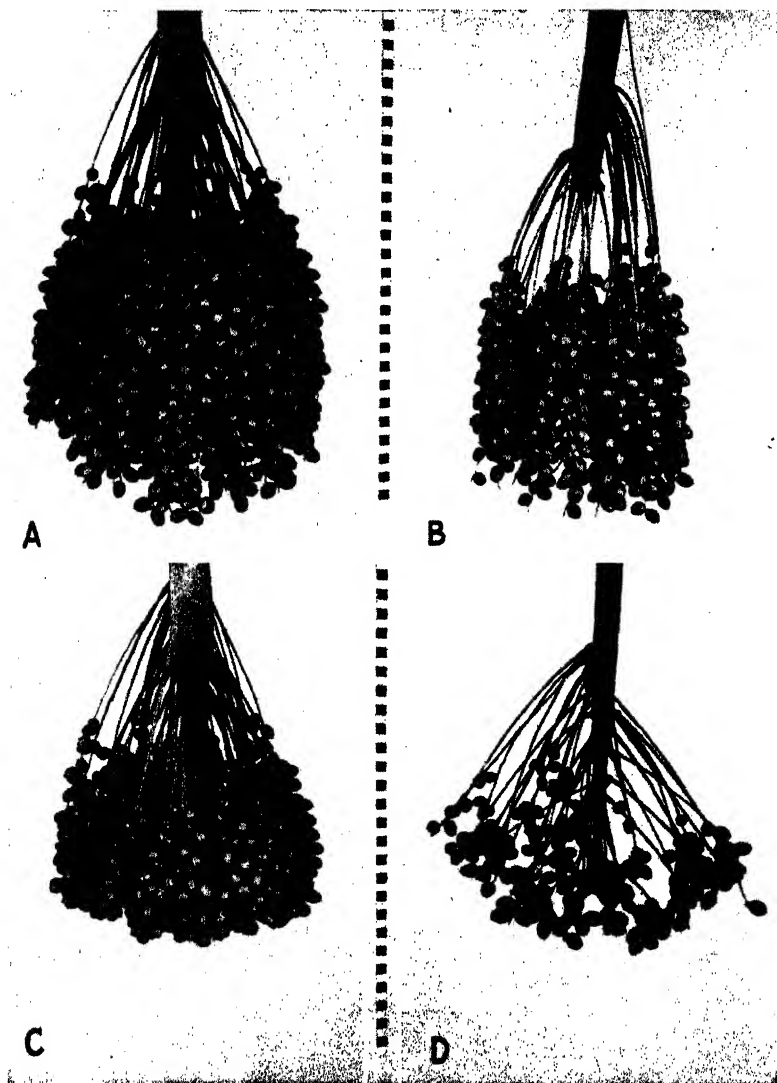


FIG. 1. Appearance on June 11 of typical bunches in Halawy fruit thinning treatments. A, check, 20 per cent reduction by removing entire strands from center. C, 60 per cent reduction—20 per cent by removing entire strands from center, and 40 per cent by cutting back strands. D, 90 per cent reduction—20 per cent by removing entire strands from center, and 70 per cent by cutting back strands.

green leaves carried. On those with the larger number of leaves, 56 leaves per palm were retained for the high leaf/bunch ratio and 28 for the low (see Fig. 2) ; on the smaller palms, 42 leaves per palm were



FIG. 2. Halawy palms with high and low leaf/bunch ratios. A, eight leaves per bunch. B, four leaves per bunch.

retained for the high leaf/bunch ratio and 21 for the low. In addition, for half of the palms in each of these four classifications, irrigation was withheld from July 16 until September 15.

RESULTS

Six days after the paraffined nuslin bags had been put on in treatment 5, the fruit under the covers was found covered with moisture, and in some instances a cupful of water had accumulated in the bottom of the bags. This had already caused considerable checking and splitting of the fruit and mold was beginning to develop in the centers of the bunches. Also some fruit on the periphery of the bunch near the paraffined bag showed varying degrees of sunburn. Therefore, the bottoms of the bags were opened and the bunches shaken to remove rotting fruit and water. It was evident that high temperatures and high relative humidities under the bags had injured much of the fruit.

Fresh and dry weights were obtained from samples of 20 representative fruits from each bunch on each palm on August 4, when the fruit was just beginning to show the yellow color of the *khalal* stage, and again on September 16, when ripening was well advanced. Immediately prior to September 16 determinations were made of the percentage of fruits ripe, slightly shriveled, moderately to severely shriveled, slightly checked, and moderately to severely checked, based on counts of not less than 25 fruits (number varying from 25 to 100 or more) on at least four typical strands distributed throughout the bunch. The wrinkling of fruit in the *khalal* stage was taken as an indication of shrivel.

No significant differences between the wet and dry plots, nor between the high and low leaf/bunch ratios were evident in the fresh or dry weights per fruit, in maturity, or in amount of checking. However, the average for each thinning treatment on all 32 palms, presented in Table I, when subjected to analysis of variance (3), showed some statistically significant differences in relation to thinning.

TABLE I—WEIGHT, MATURITY, AND CHECKING OF HALAWY FRUIT FROM DIFFERENT THINNING TREATMENTS

Thinning Treatments									
Measurements	1. Check	2. Moderate Strands Removed	3. Moderate Strands Cut Back	4. Very Severe Strands Cut Back	5. Same as 3 Plus Bagging	6. Same as 3 But Delayed	Odds†	Least Differences for Significance at	
								5 Per Cent Level	1 Per Cent Level
Average dry weight of flesh per fruit, August 4 (grams)	1.91	2.01	2.23	2.49	2.19	2.16	99:1	0.11	0.15
Average dry weight of flesh per fruit, September 16 (grams)	5.05	5.42	5.96	6.17	5.04	5.63	99:1	0.23	0.30
Average fresh weight per fruit, seed included, September 16 (grams)	10.65	11.00	11.69	11.54	12.21	10.81	99:1	0.45	0.59
Average percentage of fruit ripe, September 15	16.9	19.3	27.2	23.9	3.3*	25.7	19:1	—	—
Average percentage of fruit moderately to severely checked, September 15	25.6	24.7	29.5	21.7	39.0	30.1	99:1	6.30	8.32

*Most of the fruit about to ripen previously removed following damage by moisture and mold.
†Odds (for F value) that variance among treatments is significant.

Dry weight per fruit on August 4, and fresh and dry weights per fruit on September 16 were greater for *cutting back* strands (treatment 3) than for *cutting out* strands (treatment 2), by odds greater than 99 to 1. On August 4 very severe thinning by *cutting back* strands (treatment 4) had resulted in dry weight per fruit significantly greater than moderate thinning by *cutting back* strands (treatment 3), but by September 16 the difference was slightly less than significant at the 5 per cent level.

Delaying thinning from March (treatment 3) to June 6 (treatment 6) resulted in significantly lower dry weight and fresh weight per fruit on September 16.

There were no significant differences among treatments for the percentage of fruit ripe September 15. The low figure of 3.3 per cent for treatment is largely due to the fact that nearly all the fruits about to ripen were shaken off August 19, following damage by moisture and mold. It was noted that fruits on the check bunches were somewhat later in ripening than in any of the other treatments. Although not statistically significant when measured on September 15, these differences became more noticeable as the season advanced, until on nearly every palm some fruit on the check bunches remained immature after all the fruit in all the other treatments had ripened.

The percentages of fruit moderately to severely checked were unusually high in all treatments, with the highest for the bagged bunches.

The lower percentage of checking of fruits for bunches severely cut back than for those moderately cut back, was associated with a greater amount of shrivel. This low percentage of checking for bunches severely cut back might be related to the greater exposure of the fruit to sun and air movement.

The percentage of shriveled fruit for the different bunch thinning treatments in each of the wet and dry plots in each of the high and low leaf/bunch ratio plots are summarized in Table II. The highest

TABLE II—EFFECT OF AMOUNT AND KIND OF BUNCH THINNING OF INDIVIDUAL BUNCHES AND OF LEAF/BUNCH RATIO AND IRRIGATION OMISSION IN LATE SUMMER UPON PERCENTAGE OF FRUITS MODERATELY TO SEVERELY SHRIVELED ON SEPTEMBER 15

Leaf/Bunch Ratio and Irrigation Condition of Entire Palms	Percentage of Shriveled Fruit in Rela- tion to Thinning							Odds*	Least Difference for Significance	
	Treatment Number								5 Per Cent Level	1 Per Cent Level
	1	2	3	4	5	6	Mean of All Fruit			
Wet: high leaf/bunch ratio. . .	16	27	33	81	35	45	(33)	99:1	17	23
Wet: low leaf/bunch ratio. . .	29	26	46	72	61	48	(34)	99:1	18	25
Dry: high leaf/bunch ratio. . .	36	35	60	84	65	56	(48)	99:1	13	17
Dry: low leaf/bunch ratio. . .	29	29	48	69	43	57	(40)	99:1	13	17
Odds*								(90:1)		
Least difference for significance at 5 per cent level.								(8)		
Least difference for significance at 1 per cent level.								(11)		

*Odds (for F value) that variance among treatment means is significant.

percentage of shrivel occurred with fruit on bunches with strands severely cut back (treatment 4), the differences in comparison with moderate cutting back of strands (treatment 3) being highly significant in all four plots. Moderate *cutting back* of all strands (treatment 3) showed more shrivel than *cutting out* center strands (treatment 2), differences being just significant in the wet, low leaf/bunch ratio plot and highly significant in the two dry plots. Neither paraffined muslin bags nor delayed thinning (treatments 5 and 6) resulted in any significant change in the amount of shrivel as compared to treatment 3.

When all fruits from all treatments were taken as a unit on each palm, the palms with the high leaf/bunch ratio in the dry plots showed a higher average percentage of fruits shriveled than those with the low leaf/bunch ratio on the dry plots or those with either leaf/bunch ratio in the wet plots.

After it became apparent that thinning by cutting back all strands had increased both shrivel and dry weight above the amounts for the checks or for bunches with strands cut out, a comparison was made of shriveled and normal fruit on the same bunch. Ten shriveled and 10 normal ripe fruits were selected from each of 22 different bunches representing treatments 1, 2 and 3; and dry weights were determined. The dry weight of the normal fruit was consistently higher than that of the shriveled fruit, the average difference of .53 gram per fruit being highly significant.

DISCUSSION

In these experiments the dry weight per fruit was definitely increased by fruit thinning, the highest dry weight per fruit occurring with the 90 per cent removal of flowers or fruits (treatment 4). The failure of treatment 4 to show any increase in fresh weight per fruit as compared with less severe thinning (treatment 3) was probably due to the increased shrivel and excessive dehydration of fruit in treatment 4. Typical fruit bunches and strands from the different thinning treatments are shown in Fig. 3. In treatment 4, where 90 per cent of the flowers or young fruits were removed, most of the fruits showed pronounced shrivel early in the *khalal* stage and only a small proportion showed any tendency to soften with any approximation of normal ripening. The bunches in treatment 4 carried such a small weight of fruit that the stalks would not bend normally but remained more or less erect and there was a spread between strands that gave almost every individual fruit complete exposure to sun and currents of dry air. This undoubtedly accentuated the shrivel. In fact, exposure was the most obvious factor involved in shrivel, since it occurred mostly on the periphery of the bunch. Bunch 3 in Fig. 3, A shows the short and broad cylindrical mass of fruit resulting from treatment 3, in comparison with approximately the same number of fruits in a cylindrical mass of approximately equal breadth and length resulting from treatment 2. Obviously there are more outside fruits in the former treatment than in the latter and it was these outside fruits that were most affected by shrivel. This suggests that it may be desirable to protect the fruit from sun and drying air currents in late summer as is done in some parts of the Old World.

Casual observations of the bunches and of some tagged fruits indicated that, except when shrivel was pronounced in the *khalal* stage, most of the fruit softened into a marketable product. It was not practicable in this experiment to obtain the complete grade records of the ripe fruit necessary for satisfactory evaluation of the effects of thinning in terms of commercial grades. However, the less amount of shrivel on bunches with center strands *cut out* than with all strands moderately *cut back* indicates that, where shrivel of Halawy fruit is serious, bunch thinning by *cutting out* center strands may be a more desirable commercial practice.

The fact that greater shrivel developed from the high leaf/bunch treatment in the dry plot than from the low leaf/bunch treatment in the same plot or from either leaf/bunch treatment in the wet plot, suggests that water deficits in the palms in August or early September increased shrivel. However, the observed responses of the fruit to water deficits and reduced leaf area per bunch may not have been typical of palms bearing heavy crops annually. These palms carried a very light crop in 1940; accordingly the carbohydrate reserves in the trunk (1) may have been relatively high. Hence, if the supply of sugar from the leaves was reduced either by water deficits or by the reduced leaf area per bunch, such reduction may have been largely offset by utilization of reserves.

The possibility exists that thinning may result in some change in



FIG. 3. A, typical bunches in treatments 1, 2 and 3 as they appeared when the fruit first began to ripen. The waterproof covering over No. 5 appears in the background. B, typical strands showing fruit with slight shrivel as it appeared in treatments 1 and 2, more shrivel in treatment 3, and excessive shrivel in treatment 4.

the composition or structure of the cuticle or epidermal layers of the fruit making it more susceptible to dehydration. It seems probable that the factors in heavy thinning that make Deglet Noor fruit more sus-

ceptible to checking and blacknose (2), also make the Halawy fruit more susceptible to shrivel. That this dehydration of Halawy is not due primarily or entirely to a deficiency of dry matter is indicated by the fact that where bunch thinning increased shrivel, dry matter per fruit was also increased. Therefore, the tentative conclusion seems justified that the factors which result in increased dry matter per fruit also increase the susceptibility of Halawy fruit to shrivel. On the other hand, once shrivel is initiated it probably prevents the maximum accumulation of dry matter since a comparison of shriveled and normal fruits from the same bunches indicated that, when other factors are equal, shrivel is associated with lower dry weight per fruit.

SUMMARY

Different methods and amounts of bunch thinning were applied to different bunches on each of 32 date palms, thus giving 32 replications of each treatment. Irrigation of half of the palms was withheld from mid-July to mid-September. There was only a very slight increase in fruit shrivel as a result of cutting out center strands as compared with check bunches; but an equivalent amount of thinning by cutting back strands resulted in a considerable increase in shrivel on all palms, the difference being highly significant in the dry plots.

An extreme treatment in which strands were cut back so as to leave only two or three dates per strand (total reduction 90 per cent) caused such excessive shrivel that practically all the fruit was worthless. Most of the shrivel in all treatments occurred on the periphery of the bunch where exposure of the fruit to the sun and air movement was greatest. The importance of adequate irrigation with the Halawy variety was suggested by an increase in shrivel in some of the plots where water was withheld in late summer.

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Effect of Growth Substances on Flowering of the Pineapple Under Florida Conditions

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IT IS known from the work of Roderiquez (5) and Collins (2) that certain unsaturated hydrocarbon gases, such as ethylene and acetylene, induce premature differentiation of pineapple flowers and earlier bloom than normal. Recent experiments conducted in Florida by Cooper and Reece (3) have shown that pineapple plants of the Abachi variety, which normally flower in January, can be induced to flower any time during the preceding summer or fall by treatment with either ethylene or acetylene.

Coincident with the experiments with the hydrocarbon gases, a number of the synthetic growth substances, including indoleacetic acid, naphthaleneacetic acid, and naphthalene acetamide, were also tested for their effect on flowering. The two naphthalene compounds, under certain conditions were found to induce premature flowering, while the indole compound was ineffective.

Clark and Kearns (1) have just reported that, in Hawaii, flowering of the Smooth Cayenne variety can be induced in advance of the normal period, or delayed until much later by appropriate concentrations of naphthaleneacetic acid, naphthalene acetamide, and naphthalene thioacetamide. This paper, accordingly, compares the results obtained in Florida with those now reported for Hawaii.

GROWTH SUBSTANCE TREATMENTS

The experiments in Florida were conducted during 1940 and 1941 on plants of the Abachi variety grown in the field at the Flatwoods Plantation, Lake Worth, Florida. In 1940 naphthaleneacetic acid was applied in three different concentrations (.01, .005, and .001 per cent) on July 26, and in a single concentration (.01 per cent) to separate plants on October 15 and November 15. The compound was applied in a 1 per cent oil emulsion spray by covering the entire plant surface and filling the center of the plant.

Plants treated in July with the .01 and .005 per cent solutions showed considerable constriction in those portions of the stem and leaves which were developing from the apical meristem at the time of the hormone application. These constrictions became evident as development of the plant advanced. Several months after the treatment the plants were dwarfed in size as compared with untreated plants (Fig. 1). Most of the plants apparently recovered from the treatment after about 4 months. Many new and normal leaves grew out sometime after the spray was applied. These plants flowered¹ at the same time as untreated plants. However, a few of the plants which were still dwarfed in December did not flower until several months later.

¹Began differentiation about December 1. Inflorescence just visible externally about January 15.



FIG. 1. Pineapple plants dwarfed by growth substance treatment in July. Plants on left sprayed with .01 per cent naphthaleneacetic acid; plants on right untreated. Photographed 7 weeks after treatment.

The .001 per cent solution of naphthaleneacetic acid applied on July 26 caused very little constriction of the young leaves. Treated and untreated plants flowered at the same time.

Results from the October 15 application were, however, quite in contrast to the July 26 results. The .01 per cent solution induced flowering in 58 per cent of the plants 4 weeks in advance of that on untreated plants. This treatment caused a slight constriction of the young leaves but not nearly as much as the July application produced. This leaf constriction, however, did not appear to interfere with the differentiation of flower primordia.

Plants sprayed with .01 per cent naphthaleneacetic acid on November 15 flowered normally. Since untreated plants began flower differentiation shortly after November 15 (about December 1), no significant difference in time of flowering was observed. There was certainly no delay in flowering induced by the November 15 treatment.

The experiments were repeated in 1941 on a more elaborate scale. Separate lots of plants were treated in July, August, September, and October with naphthaleneacetic acid, naphthalene acetamide, and indoleacetic acid in comparison with ethylene and with no treatment. The results are shown in Table I.

Young inflorescences became externally visible on untreated plants sometime between January 15 and February 15. Ethylene treatments caused flowering considerably in advance of these dates, July 24 treatment causing flowering in August, and an August 17 treatment producing flowering in September. However, naphthaleneacetic acid sprays in concentrations of .01, .005, and .001 per cent applied on

TABLE I—COMPARISON OF EFFECTIVENESS OF ETHYLENE AND GROWTH SUBSTANCES IN INDUCING PREMATURE FLOWERING IN THE PINEAPPLE

Compound	Concentration (Per Cent)	Date Treated	Date Plants "Show Red"* at Center	
			Premature	Normal
Untreated.....	—	—	—	Jan 15 to Feb 15
Ethylene.....	†	Jul 24	Aug 20	—
	†	Aug 17	Sep 28	—
	†	Sep 17	Nov 1	—
	†	Oct 17	Dec 2	—
Naphthaleneacetic acid.....	0.01	Jul 24	—	Jan 15 to Feb 15
	0.005	Jul 24	—	Jan 15 to Feb 15
	0.001	Jul 24	—	Jan 15 to Feb 15
	0.01	Aug 28	—	Jan 15 to Feb 15
	0.005	Aug 28	—	Jan 15 to Feb 15
	0.01	Sep 25	—	Jan 15 to Feb 15
	0.01	Oct 15	Dec 15	—
	0.005	Oct 15	Dec 15	—
	0.001	Oct 15	Dec 15	—
	0.0005	Oct 15	Dec 15	—
Naphthalene acetamide.....	0.01	Jul 24	—	Jan 15 to Feb 15
	0.01	Aug 28	—	Jan 15 to Feb 15
	0.01	Oct 15	Dec 15	—
	0.005	Oct 15	Dec 15	—
	0.001	Oct 15	—	Jan 15 to Feb 15
Indoleacetic acid.....	0.1	Jul 24	—	Jan 15 to Feb 15
	0.01	Jul 24	—	Jan 15 to Feb 15
	0.01	Aug 28	—	Jan 15 to Feb 15
	0.01	Oct 15	—	Jan 15 to Feb 15
	0.005	Oct 15	—	Jan 15 to Feb 15
	0.001	Oct 15	—	Jan 15 to Feb 15

*The first external evidence of the inflorescence is the appearance of red leaves attached to the peduncle.

†Exact concentration unknown. Ethylene was applied under a tent covering 72 plants at the rate of approximately 4 cubic centimeters per minute for 24 hours.

July 24 caused no advance in flowering. Likewise, solutions of .01 and .005 per cent applied on August 28, and a .01 per cent solution applied on September 25 caused no premature flowering. On the other hand, .01, .005, .001, and .0005 per cent solutions when sprayed on the plants on October 15 all induced flowering at least a month in advance of the normal date. Therefore, under the conditions of these experiments, applications of naphthaleneacetic acid in these concentrations were not effective in inducing premature flowering until a date somewhere near October 15, which is approximately 6 weeks before normal flower differentiation.

These results with the .01 per cent naphthaleneacetic acid treatments differ considerably from those obtained in Hawaii. The data of Clark and Kearns (1) show that the .01 per cent solution applied one month prior to normal differentiation delayed flowering 3 months beyond the normal time of flowering. Thus, the same treatment that caused a hastening of flowering in Florida caused a delay in flowering in Hawaii.

In Hawaii flowering was hastened only with solutions of low concentrations in the range of .001 and .006 per cent. The only data presented indicate that these solutions were sprayed on the plants 4 months prior to normal differentiation. Under Florida conditions that would be approximately August 1, since normal differentiation begins

about December 1.² The .001 per cent solution was applied in Florida (see Table 1) on July 24 and on October 15. As mentioned previously, only the October 15 application was effective. The .005 per cent solution (nearest to their .006 per cent solution) was applied on July 24, August 25, and October 15 and only the last of these applications was found to hasten flowering. While it appears from present data that under Florida conditions this compound effectively hastens flowering only when applied as late or nearly as late as October 15, the .001 per cent and lower concentrations should be tested at dates between July 24 and October 15 on the chance that these low concentrations might be effective earlier.

The results obtained for naphthalene acetamide (Table I) are similar to those for naphthaleneacetic acid except that in the October 15 test only the .01 and .005 per cent solutions were effective, while the .001 per cent concentration was ineffective. Indoleacetic acid, on the other hand, was ineffective at all times. This was true of concentrations ranging from .1 to .001 per cent. In this connection, it was also noted that the indoleacetic acid, in any of the concentrations tested, did not produce the typical distortion and constriction of stem and leaves such

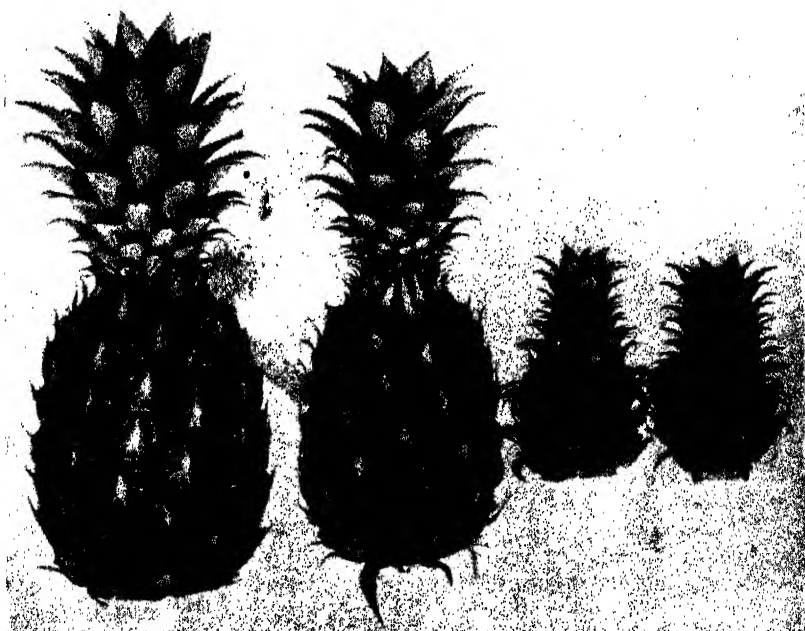


FIG. 2. Growth substances inhibit flower development in plants treated with ethylene in July. Fruits on left from plants treated only with ethylene; fruits on right from plants sprayed with .01 per cent naphthaleneacetic acid immediately after an ethylene treatment.

²Normal time for differentiation in Hawaii is about December 20 (Kearns, Collins, and Kim (4).

as was observed for naphthaleneacetic acid and naphthalene acetamide in .01 per cent concentration.

COMBINED TREATMENTS OF ETHYLENE AND GROWTH SUBSTANCE

The results described above have shown that .01 per cent naphthaleneacetic acid induces flowering only when applied in October, while ethylene induces flowering at any time during the summer and fall. In an attempt to gain more information on the effects of these two substances, a series of experiments was conducted in which ethylene and naphthaleneacetic acid were applied to the same plants.

It was found that when .01 per cent naphthaleneacetic acid was sprayed on the leaves in July, either just before or within a few days after an ethylene treatment, the plants, in some cases, did not flower, while in other instances the inflorescences that developed contained a high percentage of undeveloped flowers. Typical fruits obtained from such combined treatments are illustrated on the right in Fig. 2. Fig. 3 shows fruit obtained from a July 25 ethylene treatment followed 3 days later by a spray of .01 per cent naphthaleneacetic acid. A collar where flowers did not develop is noted midway on the fruit. In this instance, apparently flower differentiation took place over a period of a week or more, and the naphthaleneacetic acid inhibited the development of only those flowers which were being differentiated at the time of the application. If, however, the hormone was sprayed on the plants 2 weeks after the ethylene treatment, that is, after primordia were differentiated, normal flowers were produced. Apparently naphthaleneacetic acid treatments in July



FIG. 3. Fruit produced on plants treated with ethylene on July 25 and sprayed with .01 per cent naphthaleneacetic acid 3 days later.

were produced. Apparently naphthaleneacetic acid treatments in July

tend to inhibit formation of normal flower primordia on ethylene treated plants.

The results were quite different from experiments made in October. Plants receiving the combined ethylene-naphthaleneacetic acid treatment applied simultaneously produced normal flowers and flowered at the same time as those plants which received a single treatment of either ethylene or the growth substance.

DISCUSSION

It is apparent from these data that pineapple plants under Florida conditions react differently to naphthaleneacetic acid treatments in the fall and in the summer. October treatments over a wide range of concentrations induced premature flowering, while July treatments in the same range of concentrations did not induce flowering. Ethylene, on the other hand, induced flowering equally well in the summer and fall. Therefore, the nature of the effect of naphthaleneacetic acid and of ethylene on flowering apparently is not identical.

The plants in July and October differed in a number of respects. July plants were younger and were growing vigorously in a hot moist climate. October plants were older, larger, and vegetative growth had slowed down. The weather was considerably cooler in October than in July, and also the length of day was shorter. Just how these external conditions may have affected the results is not known. The differences in results of the Hawaii and the Florida experiments may possibly be attributed to the different conditions under which the plants were grown. Rainfall, soil, fertilizer practice, length of day, and temperatures differ considerably in the two regions.

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Development of the Storage Disorder Brown Core in McIntosh Apples¹

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THE storage disorder described by Carrick (3) as core browning, by Davis and Blair (4) as core flush, and by Rasmussen (11) as brown core, has in some years taken a heavy toll from the stored McIntosh apples in New Hampshire. In 1937 Rasmussen (11) published his observations on the effect of storage temperature and delayed storage on the development of this disorder with descriptions and illustrations of affected fruits. He points out that brown core differs from the brown heart described by Kidd and West (7) in that high concentrations of carbon dioxide are not necessary for its development, and differs from internal browning described by Overholser, Winkler and Jacobs (10) in that, whereas brown core originates in the core area, which Kraus (8) considers pith tissue, internal browning of the Yellow Newtown apples occurs near the primary vascular bundles. .

Brown core in McIntosh apples can be materially lessened by storing at temperatures of 38 to 40 degrees F, (2, 4, 5, 9, 10). However, the storage life of the fruit is greatly shortened over that stored at 32 degrees F (6) unless controlled atmospheres are employed. McIntosh apples have been kept until July 1 with complete freedom of brown core by use of controlled atmospheres (12).

Davis and Blair (4) found evidence that placing apples in cold storage when just at the climacteric of the respiration curve induced rapid core flush development. They also stress the value of nutritional balance in maintaining keeping quality as was evidenced by the greater susceptibility to core flush of apples from certain trees which had received a large amount of phosphorus in proportion to nitrogen.

In March 1939 the unusual amount of brown core developing in stored McIntosh apples was brought to the attention of the New Hampshire Experiment Station. In one storage of 300,000 boxes of McIntosh apples collected from various growers throughout the state, careful records had been kept of the storage condition of the apples from the different growers for several years. A study of these records showed that brown core was more prevalent in some years than others, and that apples from certain growers' orchards were subject to this disorder, while other growers' fruit was rarely troubled. This particular storage was held at 30 to 33 degrees F. The apples were put into the storage as quickly as possible after harvesting, which, according to the results of Rasmussen and other workers, is conducive to the development of brown core. Since the apples from certain orchards tended to develop brown core while apples from other orchards rarely had brown core, although held under the same conditions, it seems that there must have been some differences in the apples before they reached storage. Therefore, a study was begun to determine these differences.

¹Scientific Contribution No. 6, Biological Institute, University of New Hampshire.

Nineteen lots of apples from as many orchards and showing varying degrees of brown core were removed from this storage and studied critically. The fertilizer treatment in the orchard, relative maturity date in the locality in which the fruit was grown, date of harvest, relative ripeness of the fruit as indicated by the ground color, and amount of brown core occurring in storage were determined. In examining these lots of fruit, a total of 6,000 apples were cut crosswise and classified according to the amount of brown core as none, trace, medium, and severe. A numerical value was given to the ground color by comparison with the color charts published by Magness, *et al.* (9).

Data for five lots typical of the whole, presented in Table I, indicate a possible positive correlation between greenness in ground color and number of fruits with brown core. This suggests that lack of maturity

TABLE I—INFLUENCE OF FERTILIZERS AND MATURITY ON BROWN CORE, MCINTOSH APPLES STORED AT 32 DEGREES F AND EXAMINED APRIL 26, 1939

Lot No.	Fertilizer Applied Per Tree (Lbs)	Fruit District No.*	Received at Storage	Ground Color Per Cent of Fruits		Apples With Brown Core (Per Cent)
				Yellow	Green	
252.....	15 KNO ₃ + 12 Superphosphate	1	Sep 15	84	16	17
5268.....	8 KNO ₃	2	Sep 11	49	51	89
5018.....	Manure	2	Sep 9	78	22	79
226.....	6 NaNO ₃	4	Sep 19	29	71	89
306.....	5 NaNO ₃	4	Sep 13	62	38	33

*Producing districts. Fruit specialists estimate that fruit matures about 4 days earlier in 1 than 2, etc.

at harvest time may be responsible for the amount of the trouble. There is no apparent correlation with the kind of fertilizer used in the orchards.

Stem end rot, also described by Rasmussen (11) was found affecting much of this fruit and the amount present was noted and recorded. These data were then subjected to statistical analysis and are presented in Table II. The highly significant correlations of: .774 was found between yellow ground color and absence of stem end rot; .719 between yellow ground color and absence of brown core; and, .914 between absence of stem end rot and absence of brown core. The correlation between stem end rot and brown core suggests these two disorders are associated, and that both disorders probably result from a common cause. Their absence in fruits of yellow ground color as indicated by

TABLE II—CORRELATIONS OF STEM END ROT, BROWN CORE AND YELLOW GROUND COLOR IN 6,000 MCINTOSH APPLES*

x = fruit with yellow color
y = fruit without stem rot
z = fruit without brown core

rx_y = .774 yellow—no stem rot
rx_z = .719 yellow—no brown core
ry_z = .914 no stem rot—no brown core

*The above correlation coefficients are highly significant since from Table 7.2 in *Statistical Methods* by Snedecor, a correlation coefficient of .081 is significant at the 1 per cent level with 1,000 degrees of freedom and there are nearly 6,000 degrees of freedom in these samples.

a correlation of .774 and .719 suggests again that immature fruits were subject to these disorders.

To test further the effect of maturity on brown core, three 18-year-old McIntosh trees carrying a good crop of apples were selected the following year. One had received no fertilizer; another had received normal applications of cyanamid (5 pounds per tree), and a third had received normal applications of sodium nitrate (6½ pounds per tree) for the previous two years. The fruit from each tree when harvested was divided into two lots on the basis of ground color. These fruits were stored at 32 degrees F, and on April 3 were observed for brown core. The results presented in Table III give further evidence that

TABLE III—INFLUENCE OF MATURITY ON BROWN CORE; MCINTOSH APPLES HARVESTED OCTOBER 7, DIVIDED INTO LOTS OF DIFFERENT GROUND COLOR AND HELD AT 32 DEGREES F (1939-1940)

Fertilizer Treatment	Ground Color*	Per Cent Brown Core April 3, 1940
Tree 42, control.....	3.03	None
	2.37	None
Tree 62, 5 pounds cyanamid.....	2.80	3
	2.40	7
Tree 74, 6½ pounds nitrate.....	2.43	3
	1.97	10

*Values for ground color were obtained by use of the color chart published by Magness, et al. (9)

immaturity may be conducive to the development of brown core. However, only 10 per cent of the apples were affected on April 3. It so happened that 1939-1940 was a season in which very little brown core developed in any New Hampshire storages.

At the New Hampshire Experiment Station from 1935 to 1940 McIntosh apples had been harvested at five different picking dates each year from full bearing McIntosh trees receiving various applications of fertilizer, and stored at 32 degrees F. During this same period lots of apples harvested at the time of commercial picking were stored at 32 degrees F after being held at higher temperatures for varying lengths of time. The results from one year to the next did not agree, and it was found, by observation of the data, that on years in which brown core was slight, there seemed to be some evidence of control by late picking and some indications that lighter applications of nitrogen were helpful. However, in years of severe brown core development later dates of picking and reduced fertilizer applications seemed to be ineffective in giving any appreciable control.

Table IV presents observations of brown core development in 1940-41, in apples harvested on different dates from the north and south side of the trees. This was a year of severe brown core and except for the last picking date, time of harvest had little effect on the development of the disorder. It was statistically significant, however, that in all cases, more brown core developed in apples from the north side of the tree than from the south side. This is in agreement with the observations of Bratley (1) who found that Rhode Island Greenings from the north side of the tree were more susceptible to this disease.

TABLE IV—INFLUENCE OF HARVEST DATE AND LOCATION OF FRUIT ON TREE ON BROWN CORE DEVELOPMENT; MCINTOSH APPLES FROM THE NORTH SIDE AND FROM THE SOUTH SIDE OF TREE, STORED AT 32 DEGREES F (1940-1941)

Date Picked	Per Cent Brown Core on February 11		Per Cent Brown Core on April 6	
	North	South	North	South
Sep 12.....	0	0	41*	38
Sep 19.....	11	7	63	36
Sep 27.....	4	3	52	41
Oct 3.....	4	1	41	39
Oct 11.....	23	20	69	62
			266	216
			Difference = 50	

*From Analysis of Variance. $F = 8.62$. Significant difference for total difference north and south sides = 47 when $P = .05$.

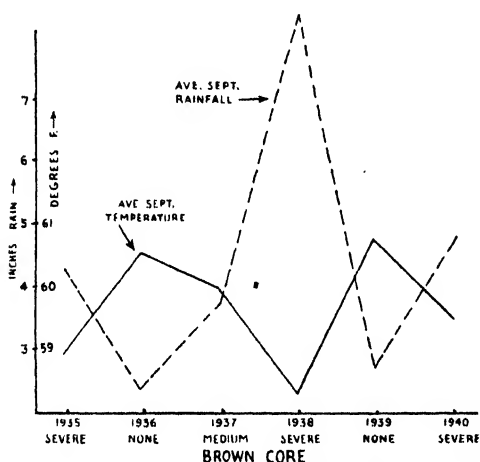


FIG. 1. Rainfall at Durham, New Hampshire, compared with incidence of brown core in McIntosh apples.

temperature varied inversely as the rainfall, and the relatively low temperatures (and excess moisture) were coincidental with years of susceptibility. This chart suggests that high moisture and low temperature conditions during the maturing period of the McIntosh apple may have been conducive to the development of brown core.

Overholser, Winkler, and Jacob (8) found Yellow Newtown apples to be more susceptible to internal browning when grown under the cooler growing temperatures of the Pajaro Valley. Fig. 1 made up of data from the Experiment Station at Durham, New Hampshire, indicates that the amount of brown core was associated with rainfall during the time of maturing of the fruit. It may be noteworthy that years of freedom from brown core have been relatively dry ones. The average September temperature

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Gross Morphology and Histology of Developing Fruit of the Apple

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ABSTRACT

The complete paper will appear in the *Botanical Gazette*, volume 104, September 1942.

THE gross development and principal tissue changes in the fruit of the apple from a month before full bloom throughout the growing season to fruit ripening are figured and discussed, and suggestions are made regarding the methods and the values of measurements of various parts.

The interpretation of the apple as five drupe-like carpels contained within the fleshy torus or receptacle has seemed to describe the structures which have been observed.

The curve of gross development of the entire fruit is nearly a straight line for the early summer variety (Early Harvest), but for each successively later-ripening variety (McIntosh and Rome) the curve flattens as the season progresses. Although perhaps associated with environment, the rate of growth is shown to be a varietal characteristic, in which each successively later-ripening variety has a slower rate.

The cartilaginous portion of the carpels develops rapidly for 2 to 4 weeks after full bloom, reaching maximum size in transverse diameter the earliest of any of the tissues making up the bulk of the fruit. The fleshy portion of the carpels continues growth approximately 2 weeks longer and is the next tissue to reach maximum size. The pith and cortical regions continue growth up to fruit ripening and constitute the bulk of the apple at that time.

The edges of the carpels are in approximate contact along the ventral suture up to about 4 weeks after full bloom. In such varieties as the Twenty Ounce, the edges then begin to spread apart along the ventral suture and curve away from the central axis of the fruit, resulting in an "open core" condition.

The development of the carpels resembles somewhat the development of a drupe fruit. Each carpel is composed of inner epidermis, cartilaginous pericarp, fleshy pericarp, and outer epidermis.

The cells of the inner epidermis are radially elongate 4 weeks prior to full bloom. Following full bloom the cells of the inner epidermis elongate rapidly obliquely towards the apex of the fruit and towards the dorsal carpellary bundles, except for some longitudinal strips in the region of the dorsal and ventral bundles. During the second and third months after full bloom the cell walls become greatly thickened until at fruit ripening the lumen is scarcely more than a line.

The cartilaginous pericarp increases by cell division prior to full bloom, and by cell elongation and some cell division after full bloom. During the second month after full bloom, the cell walls begin rapid thickening, which progresses until at fruit ripening the lumen is about one-fifth the diameter of the cells. There is an absence of schlerenchy-

matous cells in the region of the carpel bundles so that the hardened portions of the pericarp form two disconnected sheets of tissue, one on either side of the locule. As the fruit nears ripening the cartilaginous pericarp may become fissured or split, resulting in a tufted condition when parenchyma tissue grows between the breaks. The gross size of the cartilaginous carpel may increase by this means even after hardening is complete.

The fleshy pericarp may be distinguished from the cartilaginous pericarp at full bloom. Cell division is most abundant prior to and at the time of full bloom. Cell enlargement follows, many of the cells becoming radially elongate reaching 300 microns at fruit ripening, as compared with 10 microns at full bloom.

The pith can be recognized as early as 1 month before full bloom. There is much cell division for 11 days just at and immediately after full bloom. Cell division seems to have ceased by 3 weeks after full bloom. Increase in size of pith is due thereafter to increase in size of cell and of intercellular spaces, some cells reaching 150×300 microns.

The cortical region prior to full bloom increases rapidly in number of cells, by cell division. During the next 2 weeks there is rapid increase in both number and size. Cell division appears complete 3 weeks after full bloom so that subsequent increase in size is by enlargement of cells and of intercellular spaces, some cells attaining a size of 197×340 microns.

Cells of the hypodermal layer can be distinguished by the time of full bloom by slight thickening of the walls. Both tangential elongation and thickening of the walls continue until the fruit has attained full size.

The cells of the epidermis are palisade-like and readily distinguished at least a month before full bloom. The number of cells is more than doubled between the 25th and the 3rd day before full bloom. From the 3rd day before full bloom until the 24th day after full bloom it increases more than six times, and appears to continue to some degree until 85 days after full bloom. As the period of fruit ripening approaches there is much tangential stretching of the cells to accommodate the increasing surface area.

The development of pericarp, nucellus and integuments and embryo is similar in some details to the stages of development of similar parts in drupe fruits, but the bulk of the apple fruit, being accessory tissue, shows no such stages.

Softening and Soluble Solids in Bartlett Pears as Influenced by Soil Moisture

By F. W. ALLEN, *University of California, Davis, Calif.*

MATURITY standards for eastern shipments of California Bartlett pears are based upon color, firmness and soluble solids. In the general reports (1, 3) covering maturity investigations, begun in 1925, it was shown that color and firmness are materially influenced by location, cultural conditions and the rootstock upon which the trees are growing. Further study has been given to rootstock influences upon color and firmness and the results published (2). This present paper presents in brief form the results of additional study of the influence of soil moisture conditions upon firmness and soluble solids.

It has been shown (1, 3) that Bartlett pears from the warm, dry districts of California are of firmer texture when harvested than fruit from the cool districts where available soil moisture is generally present until rather late in the season. The results secured from many additional samples of pears collected during the past four seasons from the primary Bartlett pear districts of California are in general agreement with those secured previously on firmness and show in addition that the softer fruit of less color is also characterized by a lower level of soluble solids. This difference between districts usually exists regardless of the amount of soil moisture, although the latter appears to be an important factor in the hot, dry districts. In these districts considerable variation in firmness of the fruit has been noted between individual orchards, and because fruit in some of these was retarded in its softening, growers were forced to postpone harvesting until their fruit would meet legal firmness requirements. A study of conditions in these orchards revealed the fact that in many instances the trees were growing under conditions where the available moisture was exhausted prior to harvest.

Ryall and Aldrich (4), working with Bartlett pears at Medford, Oregon in 1937, and Haller and Harding (5), working with Rome Beauty apples in Maryland, have reported their findings that fruit grown without irrigation, or at least under a limited moisture supply, had a greater percentage of dry matter than that grown with adequate moisture and that this was reflected in a firmer flesh.

This same type of investigation has now been conducted for four years in California. Following preliminary tests in four orchards in 1937, the next year comparisons were made of the firmness and also of the soluble solids content in the fruit from 15 orchards in 8 districts. This was extended in 1939 and in 1940 to include some 25 orchards in 12 districts. Comparison was made between the fruit from irrigated and non-irrigated trees, or in certain orchards, between trees, which because of their particular location in the orchard received ample water, and those which were allowed to become dry sometime before harvest. For convenience this fruit will be referred to as "wet" and "dry". In each instance firmness of 10 pear samples was measured in the usual manner with a pressure tester having a 5/16-inch plunger point and

soluble solids content was measured by means of a Zeiss hand refractometer.

Soil samples were taken to determine soil moisture in a number of the selected orchards at different times immediately before and throughout the harvest season. In other instances, the relative amounts of available moisture were judged only by observation. In some of these orchards, comparisons were made between fruit from trees growing in soil moist enough to support a lush growth of grass and weeds, and fruit from trees on soil evidently at the wilting point, as judged by the appearance of the weed growth beneath the trees or even by the tree itself.

In Table I data of firmness and soluble solids are shown for "wet" and "dry" fruit harvested on six picking dates in 1939 and in 1940 from irrigated and non-irrigated plots of trees in a typical Placer County orchard. In each year the permanent wilting percentage in the top 4 feet of soil in the non-irrigated plot was reached relatively early.

The results show that in 1939 without any exception the fruit from the non-irrigated trees was firmer and higher in soluble solids than was the irrigated fruit. The average difference for the season was 2.6 pounds in firmness and 2.7 per cent of soluble solids. In 1940 the average difference in firmness was only 0.6 pound due to the fact that the first and last samples harvested were exceptions to the general findings. There were no exceptions in the amount of soluble solids and the average difference was 2.3 per cent. The two exceptions in firmness are only typical of what is occasionally found and are believed due to errors in sampling or testing. No satisfactory explanation can be given for the low firmness figures secured in both the "wet" and "dry" samples of fruit picked on July 16, 1939.

With the data presented from this orchard being considered typical of the numerous comparisons made, seasonal average differences are presented in Table II for the 1937 to 1940 period in the leading pear growing districts.

As would be anticipated, consistent differences were lacking in a few individual orchards, and in still others as illustrated by the 1940 data in Table I, where a seasonal difference was obtained, individual pickings were occasionally contrary to expectations. Except, however, for these relatively few inconsistencies the general averages for the orchards in each district in each year show firmness and the level of soluble solids to be greater in the "dry" than in the "wet" fruit (Table II). This average difference for all districts amounted to 1.4 pounds in firmness (a difference of 6.7 per cent) and 1.5 per cent in soluble solids (a difference of 12.0 per cent). Such differences are not large, but, since they were consistent in several hundred individual samples, they are considered significant.

As a further comparison, pears were harvested during 1939 from several orchards which were neither pruned, cultivated nor irrigated. The trees were standing in dry grass, in hard dry soil and showed unmistakable signs of drought conditions. The fruit for the most part failed to attain desirable market size. Pears collected from these neglected orchards were found to be extremely hard and high in soluble

TABLE I—FIRMNESS AND SOLUBLE SOLIDS OF BARTLETT PEARS VAN RIPER ORCHARD (NEWCASTLE, CALIFORNIA, JULY-AUGUST, 1939 AND 1940)*

<i>Firmness (Per Cent)—1939</i>							
July 1		July 6		July 11		July 16	
Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
23.4	25.5	19.8	21.8	19.5	22.3	16.6	19.9
July 21		July 31		Seasonal Average			
Wet	Dry	Wet	Dry	Wet		Dry	
20.1	23.0	17.5	20.1	19.5		22.1	

<i>Soluble Solids (Per Cent)—1939</i>							
July 1		July 6		July 11		July 16	
Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
12.0	13.8	11.6	15.3	12.0	15.7	12.9	16.8
July 21		July 31		Seasonal Average			
Wet	Dry	Wet	Dry	Wet		Dry	
14.2	15.8	13.8	15.0	12.7		15.4	

<i>Firmness (Per Cent)—1940</i>							
July 26		July 5		July 11		July 18	
Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
29.2	28.7	24.2	26.2	23.7	25.8	22.0	22.8
July 27		Aug 5		Seasonal Average			
Wet	Dry	Wet	Dry	Wet		Dry	
20.6	20.7	18.2	17.5	23.0		23.6	

<i>Soluble Solids (Per Cent)—1940</i>							
July 26		July 5		July 11		July 18	
Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
10.7	13.4	11.4	14.3	11.9	13.2	11.2	12.8
July 27		Aug 5		Seasonal Average			
Wet	Dry	Wet	Dry	Wet		Dry	
12.0	15.4	12.7	14.4	11.6		13.9	

*Picked on dates indicated.

TABLE II—FIRMNESS AND SOLUBLE SOLIDS IN BARTLETT PEARS (1937-1941)*

District	Firmness (Pounds Pressure)									
	1937		1938		1939		1940		1937-40	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Sacramento River.....	—	—	20.1	21.1	21.5	22.3	20.4	22.9	20.6	22.1
Fairfield-Vacaville.....	—	—	22.0	22.4	20.3	20.8	—	—	21.1	21.6
Martinez-Concord.....	—	—	21.4	21.9	19.9	21.5	—	—	20.6	21.7
Placer County.....	—	—	—	—	20.2	21.3	22.9	24.2	21.5	22.7
Placerville.....	17.8	20.3	21.1	21.5	21.8	24.8	20.3	22.3	20.2	22.2
Mendocino-Lake County.....	—	—	20.5	23.4	21.0	22.3	22.1	24.8	21.2	23.5
Averages.....	17.8	20.3	21.0	22.1	20.8	22.2	21.6	23.5	20.9	22.3
Average difference.....										1.4
Percentage difference.....										7.7

District	Soluble Solids (Per Cent)									
	1937		1938		1939		1940		1937-40	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Sacramento River.....	—	—	12.4	12.5	11.3	12.7	12.6	13.0	12.1	12.7
Fairfield-Vacaville.....	—	—	13.5	14.4	14.0	15.5	—	—	13.7	14.9
Martinez-Concord.....	—	—	12.3	13.2	11.4	14.6	—	—	11.8	13.9
Placer County.....	—	—	—	—	12.6	14.4	12.5	13.4	12.5	13.9
Placerville.....	13.5	15.1	12.1	13.7	11.9	13.5	12.0	13.3	12.4	13.9
Mendocino-Lake County.....	—	—	11.6	14.0	11.8	14.0	12.8	14.9	12.1	14.3
Averages.....	13.5	15.1	12.4	13.5	12.2	14.1	12.5	13.6	12.4	13.9
Average difference.....										1.5
Percentage difference.....										12.0

*Seasonal averages—two to seven pickings each season from two to six "wet" and "dry" orchards in each district.

solids. The firmness of samples picked on different dates during the season averaged from 24.4 to 26.5 pounds and the soluble solids averaged from 14.1 to 16.6 per cent.

Fruit from irrigated orchards in the same district over the same period of time had an average firmness varying between 20.6 and 22.1 pounds and soluble solids between 11.7 and 12.9 per cent (Table III). Thus, where fruit from a well-kept and well-irrigated orchard (according to commercial practice in the district) is compared with that from one growing under extreme drought conditions, the differences in firm-

TABLE III—FIRMNESS AND SOLUBLE SOLIDS IN BARTLETT PEARS FROM DRY, NEGLECTED AND IRRIGATED ORCHARDS (1939)

Orchard	District	Average for the Season			
		Firmness		Soluble Solids	
		Wet	Dry	Wet	Dry
1	Placerville	22.1	26.6	12.9	15.5
2	Orangevale	—*	25.3	—*	14.1
3	Placer County	20.6	26.0	12.9	16.6
4	Mendocino County	21.6	24.4	11.7	15.3
Average		21.4	25.6	12.5	15.6

*No longer any commercial orchards in this district.

ness and soluble solids are more than twice that found between other well-irrigated and inadequately or non-irrigated orchards.

To determine the influence of soil moisture upon the water content of the fruit, samples of 10 pears (the same specimens which were used for firmness and soluble solids tests) were weighed, sliced and dried at 50 degrees C (122 degrees F) in a dehydrator for 6 days. After this period the tissue was quite brittle and the weights nearly constant. In each of 32 comparisons the "wet" fruit contained more moisture than the "dry". The average difference as shown in Table IV was 2.6 per cent or a difference of 14.8 per cent.

TABLE IV—COMPARISON OF MOISTURE IN BARTLETT PEARS (1939)

Location	Number of Comparisons	Water Content (Per Cent)	
		Wet	Dry
Loomis.....	4	81.6	79.7
Newcastle.....	8	81.8	77.3
Auburn.....	2	82.4	80.0
Placerville.....	2	81.8	79.7
Polsom.....	1	84.5	80.4
Mendocino County.....	3	82.0	79.9
Santa Clara.....	1	81.4	79.7
Concord.....	1	83.2	80.1
Penryn.....	4	82.6	80.0
Fairfield.....	2	80.9	78.8
University Farm.....	4	82.7	80.5
Average.....		82.3	79.7
Difference in percentages.....			2.6
Percentage difference.....			14.8

The results having shown the relation between soil-moisture conditions and moisture and soluble solids contents in the fruit, further comparisons were made between the soluble solids in the juice as determined by the refractometer and total sugar in the juice as determined by analysis.

Fruit from "dry" trees averaged 15.1 per cent of soluble solids and 8.9 of total sugars on a fresh weight basis. Fruit from "wet" trees in the same orchards averaged 12.6 of solids and 7.7 per cent of sugars. The ratios of solids to sugars were in each case similar, averaging .595 in the "wet" fruit and .587 in the "dry".

Using the same fruits, comparisons were likewise made between the total sugar content and total solids in the flesh of the dried fruit. In the "dry" or non-irrigated fruit having 8.9 per cent of sugar, the total solids averaged 20.0 per cent. In the "wet" pears with 7.7 per cent of sugar, the solids were only 17.9 per cent. Ratios for "wet" and "dry" were again similar, being .446 in the former and .430 in the latter (Table V). These results lend support to the general opinion of pear growers that irrigated fruit lacks sugar inasmuch as, on a fresh-weight basis, the percentage of sugar was lower in the "wet" than in the "dry" pears.

In applying the above findings to commercial harvesting, it is seen that the same growth factors which retard softening decreases the moisture content and increase the percentage of solids and sugar in the fruit on a fresh-weight basis. Soluble solids furnish an index of

TABLE V—PERCENTAGE OF TOTAL SUGAR IN BARTLETT PEAR JUICE COMPARED TO SOLUBLE SOLIDS IN THE JUICE AND TO TOTAL SOLIDS IN THE DRY FLESH (1939)

Orchards	Wet Trees				
	Soluble Solids in Juice (1)	Total Sugar in Juice (2)	Total Solids Dried Pear Flesh (3)	Ratio	
				Column 2 to 1 (4)	Column 2 to 3 (5)
1	14.5	8.49	19.50	0.586	0.433
2	11.3	6.62	15.68	0.586	0.422
3	13.8	8.28	18.57	0.600	0.446
4	12.2	7.41	17.65	0.607	0.420
Average	12.6	7.70	17.87	0.595	0.430

	Dry Trees				
	Soluble Solids in Juice (6)	Total Sugar in Juice (7)	Total Solids Dried Pear Flesh (8)	Ratio	
				Column 7 to 6 (9)	Column 7 to 8 (10)
1	15.4	9.27	19.04	0.602	0.465
2	15.4	8.97	20.16	0.582	0.445
3	15.0	9.16	20.32	0.608	0.451
4	14.8	9.24	19.53	0.557	0.422
Average	15.1	8.91	19.99	0.587	0.446

actual sugars and may be taken therefore as an alternative picking index for fruit which on account of a restricted moisture supply remains unduly hard.

Inasmuch as soil moisture affects both the texture and composition of pears, it was of interest to make comparisons of fruit grown in 1938 following a winter in which the rainfall was approximately 33 per cent greater than normal with fruit produced in 1939 following a winter in which the rainfall was from 33 to 50 per cent less than normal. Fruit was harvested four to seven times each year from each of 20 orchards distributed in five different districts. The same orchards and same trees were used each season. Actual picking dates in 1939 were slightly different from 1938 but in each year were made at approximately 5-day intervals starting 1 week before the beginning of commercial harvest and continuing throughout the season.

In three of the larger districts out of the five, the samples harvested in 1939, the season following the dry winter, were slightly firmer than in the previous year. The general firmness average for all the orchards, however, was the same in each of the two years. The difference in soluble solids was 1 per cent greater in 1939 than in 1938, and was quite constant.

Rain in California is limited to the winter and early spring season, and in most of the foothill pear orchards at least the depth and character of soil is such that it has a relatively low amount of readily available moisture. Annual rainfall, therefore, much of which in normal years is lost by drainage, is thought to be a factor only where a portion of it may occur late enough to extend the period of available moisture

further into the season. Regardless of rainfall, irrigation in California is practiced in the better orchards in all the pear districts of the state.

CONCLUSIONS

A measurement of firmness and of soluble solids in Bartlett pears in a large number of orchards in California for a period of 4 years has shown that each of these is higher in the fruit from non-irrigated trees than from those which are irrigated.

Comparisons of soluble solids and total sugars in the juice show each to be higher in the "dry" fruit, but the ratio between the two is similar in "dry" and in "wet" fruit. This, also, was found to be true in comparing ratios of total sugars with total solids in dried pears.

The results secured have practical application in that soluble solids, easily measured by a refractometer, indicate sugars and that the same growth factors retarding softening increase sugar content. When on account of restricted soil moisture, fruit is delayed in softening, soluble solids may be used as an alternative picking index.

Quantity of winter rainfall apparently has little effect as summer irrigation is still necessary to maintain an available supply of soil moisture throughout the growing season.

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Preliminary Studies on Modified Air Storage of the Fuerte Avocado Fruit

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OBSERVATIONS on the respiratory trend of Fuerte avocados at the storage temperature of 4 to 5 degrees C and at the ripening temperature of 15 degrees C have been reported (1). A definite relationship was found between carbon dioxide evolution and softening. The maximum in the rate of respiration invariably preceded softening when the fruit was stored in ordinary air. This behavior did not occur in an atmosphere of nitrogen. Under anaerobic conditions a sharply declining carbon dioxide output took place with no characteristic climacteric and no softening. Apparently the respiratory system of the avocado is highly sensitive to complete lack of oxygen. On the other hand, a 20 per cent oxygen content, as normally found in air brought about rapid oxidation and softening. These differences between aerobic and anaerobic carbon dioxide production suggested the advisability of investigating the effects of modified atmospheres, with a view to prolonging the storage life of this fruit.

EFFECTS OF MODIFIED ATMOSPHERE NO. 1

The first modified atmosphere to which the fruit was subjected in these studies consisted of 10 per cent oxygen, 10 per cent carbon dioxide, and 80 per cent nitrogen. This gas mixture, supplied in cylinders by a commercial concern, was checked in the laboratory and the composition found to be reasonably close to specifications.

The avocados for the first experiment came from Escondido, San Diego County, and were placed in storage February 15, 1941, at a temperature of 4 to 5 degrees C. In this particular case only 12 fruits were used for each treatment. The total fresh weight of the treated sample was 2,425 grams as compared with 2,415 for the control. For several days prior to differential treatment all containers were stored under a continuous air stream, and carbon dioxide evolution determined daily by methods described previously (1). All respiration measurements were made in air. On February 24, two of the four containers were placed under modified atmosphere No. 1 which was supplied at a rate of 100 cc/minute for a period of 2 weeks. On March 10 all the fruit was transferred to air at 15 degrees C. At that time the control avocados as well as those exposed to the modified atmosphere showed no signs of softening. The effects of controlled air storage on subsequent respiration rates under air in a ripening room maintained at 15 degrees C are presented in Table I.

As may be seen from this table, the initial rate of carbon dioxide evolution was about 24 per cent lower in avocados under the modified atmosphere than in control fruit. This divergence was rapidly diminished, and the climacteric took place in both cases on March 14. Similarly, the rate of softening was not materially delayed by an exposure to the modified atmosphere for 14 days.

The period of treatment with modified atmosphere No. 1 was

TABLE I—RESPIRATION OF FUERTE AVOCADOS IN AIR AT 15 DEGREES C, AFTER PRELIMINARY TREATMENT AT 4 TO 5 DEGREES C (IN MILLIGRAMS CARBON DIOXIDE PER KILOGRAM OF FRUIT PER HOUR)

Preliminary Treatment	March					
	11	12	13	14	15	17
Air.....	87.6	98.1	101.9	104.6	96.8	82.7
Modified Air No. 1.....	66.9	79.8	91.3	98.0	94.0	83.2
	18	19	20	21	22	
Air.....	70.0	58.0	48.7	42.1	37.9	
Modified Air No. 1.....	65.3	51.9	52.8	37.1	37.2	

lengthened in a second experiment, for which avocados were obtained on March 12, 1941 from the orchard of the Division of Horticulture at Los Angeles. The fruit was divided into three equal samples. Sample A was exposed for 2 weeks, sample B for 4 weeks, and sample C for 6 weeks to gas storage at 5 degrees C. Fifteen fruits were used in each treatment and control. At the end of each storage period the respective sample and its control were transferred to air at 15 degrees C, and carbon dioxide evolution determined. In Fig. 1 the readings obtained immediately following this transfer as well as the climacteric values are presented.

The time elapsed between the initial and maximum respiration varied with the different samples. The longer the fruit was kept in storage the shorter appeared to be this time interval. Here, as in the first experiment, a 2-week treatment with modified air did not result

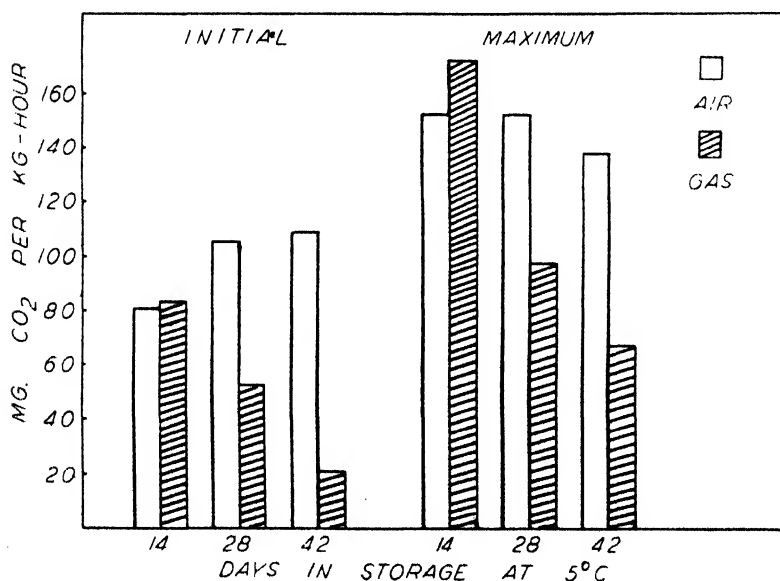


FIG. 1. Respiration of Fuerte avocados in air at 15 degrees C, after exposure to air and modified atmosphere No. 1 at 5 degrees C.

in any reduction in carbon dioxide evolution. On the other hand, samples B and C, which were two and three times longer under the modified atmosphere than sample A, showed a retarded rate of respiration. However, so far as ripening was concerned this treatment did not bring about any appreciable delay in softening nor did it prevent darkening of the skin. There were some indications that the carbon dioxide concentration in modified air mixture No. 1 lowered the keeping quality of the fruit.

From the results of the experiments conducted in the spring of 1941, it was considered advisable to lower both the oxygen and the carbon dioxide contents of the modified air mixture. Specifications were, therefore, issued for cylinders containing 2.5 per cent oxygen, 5 per cent carbon dioxide and 92.5 per cent nitrogen. The mixture actually supplied deviated considerably from this specification. The oxygen content varied from 3.6 to 5.6 per cent, and the carbon dioxide content from 2.9 to 4.9 per cent, nitrogen making up the difference. This gaseous composition will be referred to as "modified atmosphere No. 2". The results obtained with this mixture are believed to justify a report at this time. Thus far two experiments have been carried out with this modified atmosphere, one on early and the other on midseason Fuerte avocados.

EFFECTS OF MODIFIED ATMOSPHERE NO. 2

Effects of Modified Atmosphere No. 2 on Early Fruit:—For this experiment avocados picked at Escondido December 15, 1941 were placed at 7 degrees C on December 19 under a constant stream of air. Twenty fruits were included in each treatment. On December 24 one of the jars (No. 20) was placed under the modified air mixture at a rate of 100 cc/minute, while jar No. 19 was left under air at the same rate. During respiration measurements the rate was increased to the standardized flow of 350 cc/minute. The response of the fruit to modified air storage as compared with ordinary air is shown in Fig. 2.

The respiration curve of the control fruit seemed to rise to the characteristic climacteric, which was not observed previously at a storage temperature of 2 to 3 degrees lower. The largest quantity of carbon dioxide evolved at 7 degrees C was one-third to one-fourth that of avocados during the peak of respiration at 15 degrees C. The fruit in control jar No. 19 were firm on January 14, 1942, but appeared to soften on February 7. The time interval between the climacteric and onset of softening was much longer at 7 degrees C than at 15 degrees C. This observation is in conformity with the high Q_{10} for avocado respiration reported previously (1). The fruit in jar No. 20 which was stored in the modified atmosphere was found to be firm on February 7. On that day the contents in each jar were split into two equal samples. Ten avocados from jar No. 19 were transferred to jar No. 18, and 10 from jar No. 20 to jar No. 26, leaving 10 fruits in each of the original containers. All jars were placed under air at 350 cc/minute.

On February 9, jars No. 18 and No. 26 were moved to the ripening

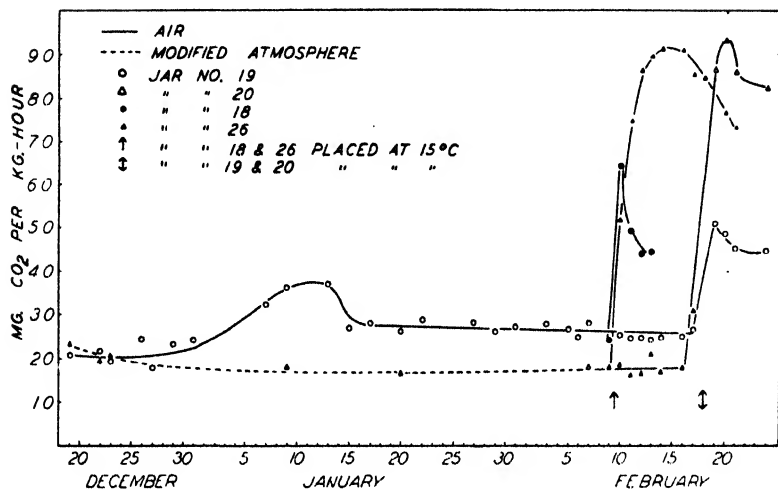


FIG. 2. Carbon dioxide production by early season Fuerte avocados in relation to controlled air storage (Modified atmosphere No. 2).

room which was maintained at 15 degrees C. In both cases a sharp rise in carbon dioxide evolution took place, but the trend of the respiration curves is strikingly different for the two samples. Jar No. 18 which had passed the climacteric at the low temperature exhibited a declining rate of carbon dioxide output. On the other hand, the fruit in jar No. 26, which was in the pre-climacteric stage when transferred to the ripening room, showed the typical increase to a maximum followed by a decrease in the rate of respiration. A similar difference in behavior was observed between jars No. 19 and No. 20 which were transferred to 15 degrees C on February 18. The effect of modified air storage for 6 weeks was also observed in the manner of ripening. The treated fruit kept firm longer and softened more gradually than that exposed to air. The former had also a more desirable appearance of the skin. In general, there seemed to be a definite improvement in the keeping quality of the fruit under the modified atmosphere.

Effects of Modified Atmosphere No. 2 on Midseason Fruit:—The avocados for this experiment were obtained from the Divisional orchard on January 21, 1942 and placed the same day at 7 degrees C under air at 350 cc/minute. Twenty fruits were included in each respiration jar. The fresh weights of the fruit were 3,855, 3,985, and 4,150 grams for jars No. 7, 9, and 11, respectively. On January 27, two jars (No. 7 and No. 9) were put under the modified air mixture at 100 cc/minute, while jar No. 11 was left as control under air at the same rate of flow as the treated fruit. Jar. No. 7 was kept under controlled atmosphere storage for 5 weeks and No. 9 for approximately 3 weeks. The effects of this treatment on carbon dioxide evolution are presented in Figs. 3 and 4.

In this experiment, as in the previous one, the respiration of the control fruit reached the climacteric at 7 degrees C. However, the

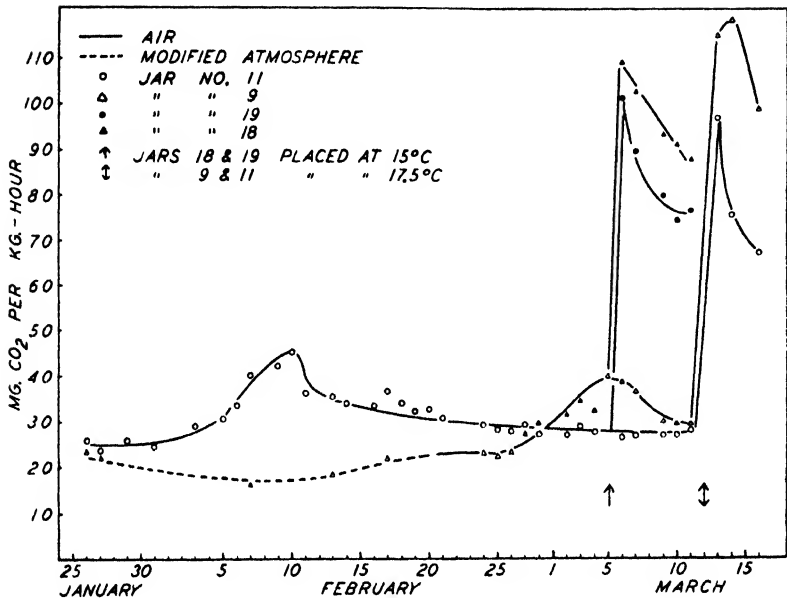


FIG. 3. Carbon dioxide evolution by Fuerte avocados as affected by controlled air storage for 3 weeks (Modified atmosphere No. 2).

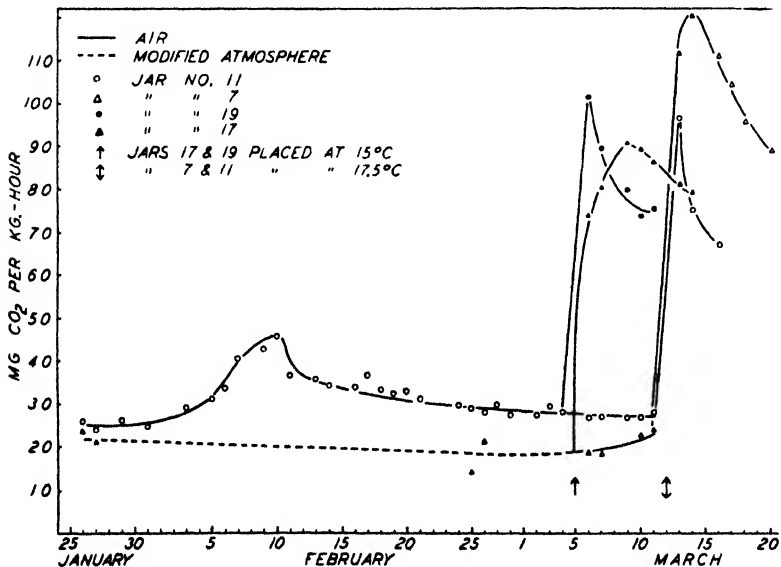


FIG. 4. Carbon dioxide evolution by Fuerte avocados as affected by controlled air storage for 5 weeks (Modified atmosphere No. 2).

time interval between the initial reading and the maximum was shorter by one week here than in the early season fruit. On February 10, all the avocados in jar No. 11 were very firm, but on March 5 some had started softening. At that time the treated fruit was still firm. On February 20 jar No. 9 was transferred to air. On March 5 half of the fruit from each jar were transferred to separate containers and placed at 15 degrees C. The following transfers were made: from jar No. 7 to No. 17, from No. 9 to No. 18, and from No. 11 to No. 19. The remainder of the fruit in the original jars was left at 7 degrees C until March 12 at which time transfers to a ripening temperature of 17.5 degrees C were made.

It is of particular interest to note the respiration curves after the changes in temperature. The avocados in jar No. 19 which were in the post climacteric stage, behaved like those of No. 18 in the early season fruit. The treated fruit (Fig. 3) which had been in air since February 20 and was at the peak of respiration at the time of transfer, followed essentially the same respiratory course as the control. On the other hand, a climacteric occurred in the avocados of jar No. 7 and No. 17 (Fig. 4), because they were under the modified air mixture until March 5, and presumably had no climacteric previously.

The observations on the effects of modified atmosphere No. 2 on softening and keeping quality support the findings in the experiment with early season fruit. On March 11 when the avocados in jar No. 19 showed many dark spots and were in the edible stage, the fruits in No. 18 were fully green and quite firm. All the fruits in jar No. 17 retained good color and were very firm. At the end of the experiment the control avocados had passed the edible stage and showed considerable discoloration of the skin. Of the treated fruits, those in jar No. 7 kept longest and had best appearance upon ripening. Doubtless, the better keeping quality of this fruit was due to modified air storage. It would be premature, however, to conclude on the basis of available data as to which is the most desirable atmosphere to be employed. For this purpose better controlled experiments are planned for next season.

CONCLUSIONS

Fuerte avocados were subjected for different periods to controlled air storage. One of the modified air mixtures consisted of 10 per cent oxygen, 10 per cent carbon dioxide and 80 per cent nitrogen. The other mixture had about one-third to one-half as much oxygen and carbon dioxide.

Of the two modified air mixtures, the second appeared to give promising results. The rate of carbon dioxide evolution was lower in controlled atmosphere storage than in air. Apparently no climacteric rise in respiration took place under treatment. Fruit softening was definitely delayed and the fresh appearance of the skin was retained longer under the second modified atmosphere than under air.

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Respiration, Internal Atmosphere, and Moisture Studies of Sweet Cherries During Storage

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MUCH of the success of the sweet cherry industry in the Pacific Northwest can be traced to continued improvement in methods of handling, precooling and transporting this highly perishable crop. Prompt removal of field heat, careful grading, and the commercial use of carbon dioxide to supplement standard refrigeration during transit have all contributed to improve the condition and marketability of sweet cherries.

Freshness, firmness, and brightness of color are important factors of quality in this fruit. These factors are greatly influenced by temperature, humidity, and the use of carbon dioxide gas. This paper presents data on the response of sweet cherries to different storage environments. It includes data on respiration, carbon dioxide content of the intercellular atmosphere, and moisture changes in the stem and fruit during various handling and storage practices.

MATERIAL AND METHODS

In the respiration studies, well composited 2-kilogram lots of Lambert cherries were enclosed in glass desiccators at storage temperatures of 31, 36, and 45 degrees F. The fruit was aerated continuously with CO₂-free air at 20 liters per hour while the respired carbon dioxide was absorbed in Truog towers containing 0.3N barium hydroxide.

The carbon dioxide in the internal atmosphere of Lambert cherries was released by refluxing 200 grams of whole fruit for 2 hours in a specially constructed (1) 1-liter Pyrex flask bearing a ground-glass connected Allihn water condenser. The latter was connected to a small extraction tower containing 0.1N barium hydroxide. During the entire period of refluxing the system was aspirated with CO₂-free air at 20 liters per hour.

The loss of moisture in the fruit was calculated by difference in weight, before and after storage, of 1-kilogram samples of material. The moisture content of the stems of Bing and Lambert cherries was obtained by drying the excised stems to constant weight in glass weighing bottles heated to 100 degrees C.

RESULTS

Respiration:—Since the carbon dioxide liberated has usually been interpreted as a measure of the respiratory intensity of fruit and vegetables, it has become generally accepted as an index of metabolism. Data pertaining to the respiration of Lambert cherries at different storage temperatures are presented in Table I. At the end of 8 days of storage, fruit held at 36 degrees F respired approximately 26 per cent faster than comparable lots held at 31 degrees, while at 45 degrees respiratory intensity was 70 per cent higher than at 36 degrees or slightly more than twice as great as at 31 degrees. Transit tempera-

TABLE I—RESPIRATION OF LAMBERT CHERRIES AS INFLUENCED BY STORAGE TEMPERATURE*

Length of Storage (Days)	Respiration (Mg CO ₂ per Kg/Hr)		
	Stored at 31 Degrees F	Stored at 36 Degrees F	Stored at 45 Degrees F
1	5.87	6.15	14.30
3	5.38	6.44	11.60
8	5.80	7.31	12.46
Average	5.68	6.63	12.78

*Harvested July 9, 1941 at optimum shipping maturity and stored immediately.

tures of 40 degrees or more are still common in most commercial shipments of sweet cherries, and the potential life of fruit carried at such temperatures is shortened accordingly.

Internal Atmospheres:—It is possible to depress respiratory intensity by increasing the concentration of carbon dioxide in the surrounding air. This fact forms the basis for much of the carbon dioxide gas storage work with fruit and vegetables, and has recently found commercial application in the shipment of sweet cherries in refrigerator cars. The degree to which respiration is depressed during gas storage is probably a function of the permeability of the fruit tissues to carbon dioxide, and the external concentration of this gas. Measurement of the carbon dioxide in the intercellular atmosphere of sweet cherries during and immediately following storage in various atmospheric concentrations of this gas should show the responsiveness of this fruit to its storage environment. Data bearing on the carbon dioxide equilibrium in the internal atmosphere of Lambert cherries are shown in Table II and Fig. 1:

In an atmosphere of 20 per cent carbon dioxide at 36 degrees F Lambert cherries accumulated 2.3 times their normal intercellular content of carbon dioxide during the first half hour of storage. After 3 hours, the partial pressure of carbon dioxide in the internal atmosphere of the fruit was in equilibrium with that of the storage air. At this time the carbon dioxide content of the internal atmosphere was approximately 4.5 times as great as that in comparable fruit in normal

TABLE II—CARBON DIOXIDE IN THE INTERNAL ATMOSPHERE OF LAMBERT CHERRIES* HELD IN AIR AND IN CARBON DIOXIDE GAS

Handling Treatment	Fruit Temperature When Sampled (Degrees F)	CO ₂ in Internal Atmosphere (Mg per 100 Grams Tissue)
At harvest.....	85	14.3
Air storage at 36 degrees F for 20 hours.....	36	13.2
0.5 hour in 20 per cent CO ₂ gas at 36 degrees F.....	36	31.1
3.0 hours in 20 per cent CO ₂ gas at 36 degrees F.....	36	59.9
6.0 hours in 20 per cent CO ₂ gas at 36 degrees F.....	36	60.8
15.0 hours in 20 per cent CO ₂ gas at 36 degrees F.....	36	60.2
6.0 hours in 10 per cent CO ₂ gas at 36 degrees F.....	36	34.1
0.5 hour air storage after removal from 20 per cent CO ₂ for 15.0 hours at 36 degrees F.....	36	20.2
1.0 hour air storage after removal from 20 per cent CO ₂ for 15.0 hours at 36 degrees F.....	36	13.1

*Harvested July 9, 1941 at optimum maturity for shipment.

air at the same temperature. Furthermore the concentration of carbon dioxide in the intercellular atmosphere of the fruit was reduced by approximately one-half when the amount in the storage air was lowered from 20 per cent to 10 per cent.

Data in Table II also indicate that the accumulated carbon dioxide in the internal atmosphere of cherries during gas storage was dissipated into normal air at a considerably faster rate than it accumulated therein during such storage. One hour after removal from such storage, the carbon dioxide content of the internal atmosphere of Lambert cherries had dropped from 60.2 milligrams to 13.1 milligrams per 100 grams of tissue and was similar to that of the control lots held in air. Finally, the data in Table II show that internal atmospheres of sweet cherries are much more responsive to changes in atmospheric concentration of carbon dioxide than to changes in temperature.

Moisture Changes:—The stem of the sweet cherry is extremely susceptible to shriveling and discoloration. Data in Table III show that Bing and Lambert cherry stems, even at relatively high storage humidities, showed a decrease of 7.6 to 17 in percentage of moisture during 9 days storage. Stems in gas storage lost less moisture than comparable lots held in air. Nevertheless it is doubtful that moisture losses in the stems are influenced by gas storage. General observations indicate that they are not, and the observed differences in Table III are probably the result of slightly higher humidities in the chamber where the gassed lots were stored. There was no significant difference in moisture loss from the stems between storage temperatures of 31 and 45 degrees F.

A delay of 15 hours prior to storage, however, resulted in an extremely large loss of moisture from the stems of Lambert cherries, this being approximately twice as great as for the check lot after 5 days storage at 45 degrees F. This fact emphasizes the need for prompt handling and storage following harvest.

Moisture losses from the fruit, on a basis of percentage of fresh weight, were roughly one-fourth of those from the stems. For the former the decreases in percentage values ranged from 2.3 to 5.7,

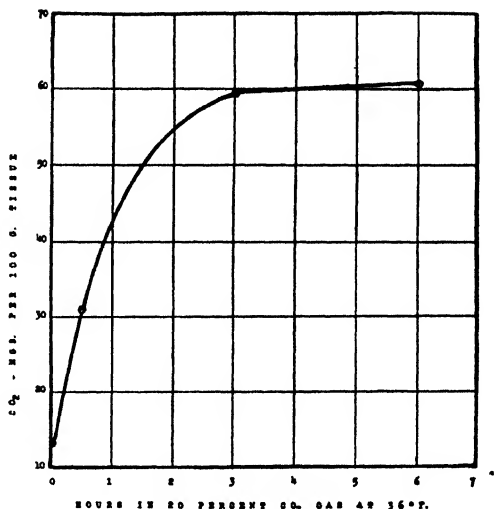


FIG. 1. Carbon dioxide in the internal atmosphere of Lambert cherries during storage in 20 per cent carbon dioxide at 36 degrees F for various lengths of time.

TABLE III—MOISTURE CHANGE IN THE STEM AND FRUIT OF BING AND LAMBERT CHERRIES DURING STORAGE

Storage Treatment	Relative Humidity in Storage (Per Cent)	Bing*			Lambert†		
		Moisture Stem (Per Cent)	Decrease in Percentage of Moisture During Storage		Moisture Stem (Per Cent)	Decrease in Percentage of Moisture During Storage	
			Stem	Fruit		Stem	Fruit
At Harvest							
None.....	—	80.0	0	0	69.5	0	0
Storage at 45 Degrees F							
5 days in air.....	90	49.1	10.9	4.0	56.6	12.9	3.8
5 days in 20 per cent CO ₂ gas.....	93	53.0	7.0	3.3	—	—	—
Delayed‡ then 4 days in air.....	90	—	—	—	47.0	22.5	4.9
9 days in air.....	90	47.4	12.6	4.8	52.5	17.0	5.7
9 days in 20 per cent CO ₂ gas.....	93	52.4	7.6	4.3	—	—	—
Storage at 36 Degrees F							
5 days in air.....	88	48.1	11.9	3.4	58.5	11.0	2.9
5 days in 20 per cent CO ₂ gas.....	93	53.1	6.9	2.3	—	—	—
9 days in air.....	88	46.5	14.5	3.8	55.7	13.8	4.0
9 days in 20 per cent CO ₂ gas.....	93	50.8	9.2	3.2	—	—	—
Storage at 31 Degrees F							
5 days in air.....	85	51.6	8.4	2.7	56.0	13.5	2.8
9 days in air.....	85	48.6	11.4	3.1	54.5	15.0	3.9

*Harvested July 6, 1941.

†Harvested July 18, 1941.

‡Delayed for 15 hours at 80 degrees F and 58 per cent relative humidity prior to storage to simulate some methods of commercial handling.

depending upon the handling and storage practice. Usually less moisture was lost at the lower storage temperatures. None of the fruit in Table III evidenced shriveling immediately upon removal from storage.

Observations on sweet cherries in terminal markets have shown that deterioration in the appearance of the stem proceeds at a surprisingly rapid rate. Data in Table IV show the change in appearance and loss of moisture from the stems of Lambert cherries under simulated transit and market conditions. Over a period of 10 days at 88 per cent relative humidity, it made little difference in the appearance or moisture content of the stem whether the fruit was held at 45 or at 36 degrees F. Furthermore this range of storage temperature did not influence the condition of the stems after removal to higher temperatures.

The humidity and temperature of the post-storage or post-transit environment, however, did influence the condition of the stems of sweet cherries to a marked degree. On a fresh weight basis there was a decrease of approximately 32 per cent in moisture in the stem after 1 day at 80 degrees F, and 50 per cent relative humidity; whereas the decrease in content was only 12.7 per cent in a similar period at 65 degrees, and 80 per cent relative humidity. Waxing after removal from storage reduced the loss of moisture from the stem but also resulted in injury and discoloration. Waxing prior to storage was not attempted. Severe shriveling and moderate browning of the stem was evident with decrease of approximately 32 per cent in percentage of moisture.

TABLE IV—APPEARANCE AND CHANGE IN MOISTURE CONTENT OF THE STEMS OF LAMBERT CHERRIES* AS INFLUENCED BY POST-STORAGE ENVIRONMENT

Post-Storage Environment	Stem Moisture (Per Cent)	Loss of Moisture During Storage (Per Cent)	Stem Color and Condition
<i>Stored 10 Days at 45 Degrees F</i>			
Upon removal.....	64.8	0	Turgid, green
Held 1 day 80 degrees F and 50 per cent relative humidity.....	33.2	31.6	Severe shriveling, moderate discoloration
Waxed,† 1 day 80 degrees F and 50 per cent relative humidity.....	54.3	10.5	Turgid, severe browning
Held 1 day 65 degrees F and 80 per cent relative humidity.....	52.1	12.7	Slight shriveling, slight discoloration
<i>Stored 10 Days at 36 Degrees F</i>			
Upon removal.....	64.9	0	Turgid, green
Held 1 day 80 degrees F and 50 per cent relative humidity.....	33.2	31.7	Severe shriveling, moderate discoloration
Held 1 day 65 degrees F and 80 per cent relative humidity.....	52.0	12.9	Slight shriveling, slight discoloration

*Harvested July 9, 1941 and stored immediately at 45 and at 36 degrees F.

†Stems dipped in a paraffin-mineral oil mixture at 90 degrees F.

The data emphasize the fact that special precautions are necessary if greenness and freshness of stem are to be preserved during the marketing of sweet cherries.

SUMMARY

Respiration of Lambert cherries at the end of 8 days was 26 per cent greater at 36 than at 31 degrees F. At 45 degrees it was 70 per cent greater than at 36 degrees, and 115 per cent greater than at 31 degrees.

After storage in 20 per cent carbon dioxide at 36 degrees F for ½ hour, the accumulation of this gas in the intercellular atmosphere of Lambert cherries was 2.3 times as great as in normal air. Within 3 hours it had accumulated to a maximum of 4.5 times normal. The rate of accumulation of carbon dioxide in the cherry was considerably less than the rate of dissipation therefrom, and the degree of accumulation appeared to be dependent upon the concentration of carbon dioxide in the storage air.

There was little difference in the appearance and moisture content of the stems of sweet cherries at comparable humidities when held at 45, 36, or 31 degrees F. Delayed storage of 15 hours at harvest induced shriveling, discoloration, and a large increase in loss of moisture from the stem during storage at 45 degrees.

Post-storage or transit environment greatly influenced the condition of stems of sweet cherries. Moisture losses for stems were more than twice as great at 80 degrees and 50 per cent relative humidity as at 65 degrees and 80 per cent relative humidity.

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Cold Resistance of Buds, Flowers and Young Fruits of Tung

By DONALD L. FERNHOLZ, *U. S. Department of Agriculture, Bogalusa, La.*

FROSTS that cause little or no permanent injury to the tung tree, *Aleurites fordii*, may destroy the blossoms and hence the crop and the grower's income for the season. This is perhaps the greatest single hazard of the tung industry in America. In three out of eight years from 1934 to 1941, inclusive, the crop was almost wholly destroyed. Slight losses occurred in certain parts of the tung belt in one additional season during this period. The damage may occur in the late winter or spring, at any time after warm weather causes growth activity and before the fruits have reached a diameter of about 1 inch. Efforts are being made to find a means of delaying the time of growth initiation in the spring. In order to provide a criterion for evaluating results obtained in delaying growth initiation, the temperatures critical for buds, pistillate flowers and young fruits at various stages of development were determined by means of artificial freezing tests.

At weekly intervals throughout the period of expected frosts, twigs bearing flower buds were collected and classified into one or more of five arbitrary groups, according to the stage of the bud development. Winter buds tightly surrounded by scales were classified as "dormant"; winter buds that had opened but showed little or no extension of the inflorescence beyond the tips of the bud scales were classified as "tight clusters"; buds having the cymose inflorescence extended to such a point that the pedicels and peduncles of the flower buds were exposed were classified as "open clusters"; the stage at which the pistillate flowers had opened was termed "at anthesis"; and after the petals had fallen the stages were termed "very young fruits" and still later "young fruits". Since some trees flower earlier than others, twigs at two or more stages of development were often obtained on the same date. For instance on March 18, 1941, some twigs with dormant buds and others in the tight cluster stage were collected.

As soon as possible after collection, the twigs were exposed to temperatures ranging downward from 32 to 24 degrees F. Regardless of the treatment, the base of each twig was kept almost constantly in water from the moment it was cut until it was discarded at the end of the experiment. Upon reaching the laboratory the twigs were arranged in bundles of 10 each. One bundle was kept at room temperature as a check and the others were placed in a freezing chamber. The temperature of the chamber was rapidly lowered to 33 degrees F, after which it was dropped one degree per hour, until 9 hours later it had reached 24 degrees F. The bundles of twigs were removed successively after each test temperature had been held an hour. For instance, a bundle of twigs to be exposed to 28 degrees F would be removed at the end of the sixth hour, the temperature having been lowered to 28 degrees F at the end of the fifth hour and maintained at that temperature for 1 hour. Thus, the lower the test temperature, the longer the corresponding bundle of twigs was in the cold chamber.

After removal from the chamber, the twigs were kept at room temperature until they were examined for injury 2 days later. Even though uninjured by cold, the staminate buds or flowers tended to drop from the clusters within 48 hours after the twigs were cut from the trees. Therefore, records were made only on the condition of the pistillate buds, flowers or young fruits and the peduncles and pedicels which support them. These were classified either as uninjured, injured, or dead. In order to summarize the data readily, uninjured buds or flowers were rated 0, injured buds or flowers 50 and dead buds or flowers 100. On this basis average injury ratings could be calculated for the buds or flowers of any one test or of a series of tests.

The data are shown in Table I. A severe early fall freeze had damaged many of these buds in November 1940, and when experimenting with dormant buds on March 12 and 18, 1941, it was impossible to

TABLE I—EFFECT OF LOW TEMPERATURES ON BUDS, PISTILLATE FLOWERS AND FRUITS OF TUNG

Stage of Development	Number Tests	Dates Tested	Average Injury Rating After Exposure to Temperatures (Degrees F)					
			Check	32	30	28	26	24
Dormant.....	2	Mar 12, 18	36	---	---	34	58	75
Tight cluster.....	3	Mar 18, 25, Apr 1	0	---	0	10	85	100
Open cluster.....	2	Apr 1, 8	0	0	0	78	100	100
At anthesis.....	2	Apr 8, 15	0	0	2	30	100	100
Very young fruit....	4	Apr 15, 22, 29, May 6	0	0	10	70	96	99
Young fruit.....	2	May 13, 20	0	0	12	22	80	100

distinguish between those that had been injured the previous autumn and those that had not been. For this reason dormant buds used as checks showed considerable injury. At the later stages of development it was possible to detect and eliminate those buds that had been injured during the previous November and only uninjured ones were used. Exposure to 28 degrees F did no harm to dormant buds, but a temperature of 26 degrees F increased considerably the average injury rating, and 24 degrees F caused very serious damage. It is to be noted that buds in a tight cluster were relatively resistant, showing an average injury rating of only 10 after exposure to 28 degrees F; but 26 degrees F killed most of the flower buds in this stage. As the flower buds pass from the tight cluster to the open cluster stage, the succulent and tender pedicels and peduncles are exposed to the air. These are very sensitive to frost. At 28 degrees F all were either killed or injured and at 26 degrees F every one was killed. By the time that the flowers opened, the pedicels had become a little more woody and were considerably more resistant to the low temperature. However, the ovaries of the flowers became increasingly susceptible to injury until after pollination and fruit setting. About 3 to 4 weeks after bloom, the young fruits became slightly more cold resistant than they were earlier, although the difference was not great. The young fruits possessed greater resistance in May than earlier but that is of little significance because there is little likelihood of frost at that late period.

It is noteworthy that before anthesis a temperature of 30 degrees F did not injure the buds. Moreover, it was repeatedly noticed that after exposure to this temperature they developed faster than the unfrozen buds used as checks.

Tung buds rapidly become increasingly susceptible to injury from low temperature as they pass from the dormant to the tight cluster and open cluster stages. At any time after they reach the tight cluster stage, exposure to 26 degrees F will destroy most of the buds. A temperature of 28 degrees F will destroy the tender pedicels and peduncles just after they emerge, but at full bloom a large proportion of the flowers can withstand this temperature. The very young fruits are more susceptible to injury than are the flowers at anthesis.

The Importance of Tung Seed Selection

By R. D. DICKEY, *University of Florida Agricultural Experiment Station, Gainesville, Fla.*

THUS far, practically all of the commercial tung plantings in Florida have been made from seed and, in all probability, for some time to come this will be true. It has been shown that wide variations exist in seedling tung trees and that these variations have an important effect upon yield and oil production (2, 3, 4). Several variations influence oil production; however, all other factors being equal, it is apparent that total yield of individual trees is the most important factor affecting production.

Since the productivity of the individual tree is of such great importance, any practice which will increase the percentage of high-bearing trees in a planting is highly desirable.

The yield records under consideration are from two blocks of trees planted on the Experiment Station grounds at Gainesville. Trees used to plant the new tung block came from a mixture of seed from the original ten trees and possibly from some other trees growing upon the Experiment Station grounds and are considered as an example of trees from unselected seed (2). They were planted in 1923 and the block now consists of 133 trees. In 1930 a block was planted on the Minor farm of open-pollinated seedlings of tree 2 and tree 9 of the original ten trees (4). The 1940 yield records of 130 and 143 trees respectively of No. 2 seedlings and No. 9 seedlings are considered. The parent tree 2 is the type tree of the Florida variety (cluster type) and parent tree 9, though a "single" type, is an exceptionally high-yielding tree (Table I). These trees are representative of seedlings

TABLE I—AVERAGE ANNUAL YIELD, AIR-DRIED HULLED SEED, OF ORIGINAL TEN TREES ON HORTICULTURAL GROUNDS (1922-1940)

Tree	19-Year Average	
	Seed (Pounds)	Oil (Pounds)
1.	20.7	7.1
2.	39.0	13.5
3.	5.5	1.9
4.	17.2	5.9
5.	4.1	1.4
6.	33.5	11.6
7.	10.2	3.5
8.	24.4	8.4
9.	68.6	23.7
10.	7.4	2.5
Average.	23.0	7.9

from selected parent trees of known high yielding ability. The new tung block and Minor farm block are upon Norfolk soils of similar fertility.

The 1940 yield data are presented in Table II. It can be seen that a much higher percentage of trees of the new tung block fall in the three lower classes and a comparatively lower percentage in the higher classes than do No. 2 seedlings and No. 9 seedlings. The largest per-

TABLE II—PERCENTAGE OF TREES IN EACH CLASS OF 1940 YIELD OF AIR-DRIED WHOLE FRUIT OF TREES IN NEW TUNG BLOCK, No. 2 SEEDLINGS AND No. 9 SEEDLINGS

Class		New Tung Block	No. 2 Seedlings	No. 9 Seedlings
No.	Limits (Pounds)			
1	0.0 to 20.0	12.8	6.2	3.5
2	20.1 to 40.0	21.8	10.0	15.4
3	40.1 to 60.0	26.3	15.4	16.1
4	60.1 to 80.0	16.5	20.8	19.6
5	80.1 to 100.0	12.0	21.5	25.2
6	100.1 to 120.0	5.3	13.1	13.3
7	120.1 to 140.0	2.3	6.2	7.0
8	140.1 to 160.0	2.3	4.0	0.0
9	160.1 to 180.0	0.0	2.3	0.0
10	180.1 to 200.0	0.0	0.0	0.0
11	200.1 to 220.0	0.8	0.0	0.0

centage of the No. 2 and the No. 9 seedlings falls in class 5, 80.1 to 100.0 pounds, while the largest percentage of the unselected seedlings falls in class 3, 40.1 to 60.0 pounds.

It is to be remembered that the trees in the new tung block are 18 years of age, while those of No. 2 seedlings and No. 9 seedlings are 11 years old, yet with this decided difference in age against them the young trees compare very favorably with the older group of trees. This point is further emphasized when the average yield per tree of air-dried whole fruit of the three groups is considered: No. 2 seedlings averaged 78.6 pounds; No. 9 seedlings 73.4 pounds; and the new tung block 57.7 pounds per tree. The importance of selecting seed from parent trees of known high-yielding ability is evident.

Statistical treatment of the data by the method of analysis of variance indicate the No. 2 is better than No. 9 by odds of only about 9:1. Hence it may be concluded that the two varieties are about equal in bearing capacity in this location in the year under consideration.

It has been shown by Newell *et al.* (4), Mowry (3), and Dickey and Reuther (2) that fruiting habit as exemplified by "single" and "cluster" type is an important factor affecting yield, and that cluster fruiting habit coupled with high yielding ability seem the best characters yet available upon which to select a superior strain. However, it was pointed out by Dickey and Reuther (2) that a tree should not be discarded for this purpose simply because it bears its fruit singly if it otherwise meets the requirements of high yielding ability. The data presented lend further support to this point.

DEGREE OF INHERITANCE IN SEEDLINGS

During the 1940 season the No. 2 and No. 9 seedlings were carefully examined to determine how closely they resemble their parent tree. The characters considered were: (a) habit of growth; (b) similarity of inflorescence to parent tree; (c) shape and size of fruit; (d) time of fruit fall, and (e) size of crop. Budded trees of No. 2 and No. 9 were present in the block for comparison. Using this data the trees were classified into six groups according to the characters constant in both seedlings and parents as follows: Five, four, three, two,

TABLE III.—INHERITANCE OF PARENTAL CHARACTERS IN OPEN POLLINATED SEEDLINGS OF FLORIDA NO. 2 AND NO. 9 TUNG TREES

Groups		Percentage of Trees in Each Group	
No.	No. Characters Similar to Parent	No. 2 Seedlings	No. 9 Seedlings
1.....	5	56.9	59.4
2.....	4	12.3	15.4
3.....	3	10.0	3.5
4.....	2	10.0	9.1
5.....	1	7.7	7.7
6.....	None	3.1	4.9

one and none. The results are summarized in Table III.

An examination of the data shows that 56.9 per cent of No. 2 and 59.4 per cent of No. 9 seedlings were very true to type, so much so that it is impossible to distinguish them from budded trees of the two varieties. Furthermore, 12.3 per cent of No. 2 and 15.4 per cent of No. 9 seedlings vary from the parent type in only one character. This means that 69.2 per cent of No. 2 and 74.8 per cent of No. 9 seedlings come fairly true to type. Finally, only 3.1 per cent of No. 2 and 4.9 per cent of No. 9 seedlings were unlike the parents in all of the characters considered.

Since seedling tung trees are so widely planted, at present, it is of interest to know that a good percentage of the seedlings come relatively true to type. These data furnish further confirmation of the reason for the superiority in yielding ability of seedlings from selected parent trees of known high yielding ability as compared to those from unselected parent trees.

It has been suggested by Camp (1) that "It is believed that if propagation by budding or grafting fails commercially the future of the tung-oil industry will, to a very considerable extent, depend upon pure line strains of high yielding varieties and, so soon as these strains have been developed by hand pollination, plantings should be made in isolated areas for the providing of pure line seed for the future". The data presented support this suggestion.

SUMMARY

Total yield is the most important factor affecting oil production. The 1940 yield of seedling tung trees from parent trees of known high yielding ability is compared with those of seedling trees from an unselected seed source. From the data presented the importance of selecting seed from parent trees of known high-yielding ability is evident.

During the 1940 season the No. 2 and No. 9 seedlings (open-pollinated) were examined to determine how closely they resemble their parent tree. Five characters were considered. It was found that 56.9 per cent of No. 2 and 59.4 per cent of No. 9 seedlings were very true to type since they were alike in all five characters used. Also, 12.3 per cent of No. 2 and 15.4 per cent of No. 9 seedlings were unlike the parent in only one character. This means that 69.2 per cent of No. 2 and 74.8 per cent of No. 9 seedlings come fairly true to type.

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The Influence of Delayed Hulling on the Color and Quality of Eastern Black Walnut Kernels

By SPENCER B. CHASE, *Tennessee Valley Authority, Norris, Tenn.*

AS EARLY as 1896, (1) it was reported that if black walnuts were gathered soon after falling from the tree and hulled promptly, the kernels would have lighter color and better flavor than if handled otherwise. Mattoon and Reed (3) have also stated that the prompt hulling of walnuts after harvesting is important if bright-colored kernels of mild flavor are to be had. MacDaniels (2) has reported that in order to get light-colored, high-quality kernels, it is necessary to remove the hull before it turns black. Walker (4) found a darkening of black walnut and butternut kernels when nuts were allowed to remain unhulled for 2 months.

Although the prompt removal of hulls as a handling method has been frequently recommended in the literature, actual data supporting this practice could not be found. The purpose of this study¹ was to determine when and to what degree the color and quality of the kernels are affected by the hull of the mature black walnut.

MATERIALS AND METHODS

During 1940, seven trees were selected for use in this study. Two trees of the Thomas variety, designated Thomas 31 and 44, were selected at random from a plantation, while the other five, designated trees 12, 13, 15, 16, and 88 were wild seedlings. No previous examination of the nuts from these trees had been made.

Each tree was kept under careful observation, and when nuts were dropping in sufficient quantity to indicate maturity of the crop, preparation for a nut collection was made by removing and discarding all fallen nuts from under the tree. The tree was then climbed, and the branches were shaken gently to remove the nuts. Only nuts which dropped as the result of this operation were used, and only one collection was made from each tree. After collection, the nuts from trees 12, 13, 15, and 16 were divided into two lots. Lot I was placed unprotected on the ground outside in wooden frames. Lot II was placed in a root cellar. The collection from the two Thomas trees and from tree 88 was not large enough to include the lot II treatment.

Within 2 hours after collection, a random sample of 100 nuts from each lot was hulled, washed in water, scrubbed with a stiff brush to remove all particles of hull, and placed in wire-bottom trays. This constituted the check treatment. Then at intervals of 1, 2, 3, 4, 6, 8, 12, 15, and 17 weeks from the date of collection, additional random samples of 10 nuts were taken from lots I and II. These samples were hulled and handled as described for the check treatment.

After hulling, the trays containing the nut samples were placed in a rack which allowed satisfactory air circulation among the trays. After

¹This is one of a series of studies being conducted by the Department of Forestry Relations to aid in the development of the black walnut kernel industry in the Tennessee Valley.

a preliminary drying period of 8 to 10 days, the walnuts were placed in suspended open-mesh bags and allowed to cure. After the 17-week samples were allowed to cure 2 weeks, all samples were cracked and examined.

To classify differences in kernel color, a color chart was prepared. A wide selection of walnuts not included in the study was cracked and the kernels arranged as to color, and from these a chart was prepared representing the range. Some kernels were definitely warm in tone while others were decidedly cold. The color rating for each sample was obtained by comparing the kernels with the color chart (Fig. 1).

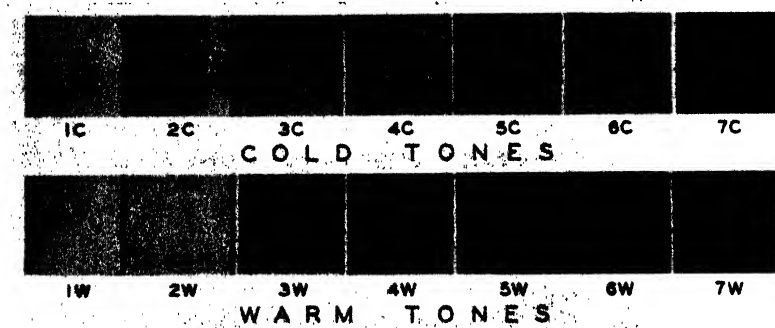


FIG. 1. The color chart used to classify kernel color.

Flavor was tested by five judges who were instructed to rate the kernels on the basis of mildness. The kernels were chopped into small pieces to offset visible condition differences.

RESULTS

Color of Kernels:—Delayed hulling caused a definite darkening of kernels from all trees. Within certain limits, the longer hulling was delayed the darker the kernels became. The effect of the hull on kernel

TABLE I—KERNEL COLOR CLASSIFICATION

Tree and Lot Number	Color Rating (1w or 1c Represents the Lightest Color)*									
	Time Hulling was Delayed (Weeks)									
	Hulled Immediately	1	2	3	4	6	8	12	15	17
Thomas 31, lot I...	1w	2w	3w	3w	3w-4w	4w	4w	5w-6w	6w	6w
Thomas 44, lot I...	1w	1w-2w	2w	3w	2w-3w	4w	4w-5w	5w-6w	6w	6w
Tree 12, lot I...	1w	1w	2w	2w-3w	2w-3w	3w	3w	3w	3w	3w-4w
Tree 12, lot II...	1w	1w	1w-2w	2w-3w	2w	3w	4w-5w	4w-5w	—	—
Tree 13, lot I...	2c	3c	4c	4c-5c	4c	4c-5c	5c-6c	5c-6c	5c-6c	5c-6c
Tree 13, lot II...	2c	3c	4c-5c	4c-5c	5c-6c	6c	6c	6c	6c	—
Tree 15, lot I...	1c	2c	2c-3c	3c-4c	3c-4c	4c	5c	5c	5c	6c
Tree 15, lot II...	1c	2c	2c-3c	3c-4c	4c	5c	5c	5c	6c	7c
Tree 16, lot I...	2c	3c	4c	4c	4c-5c	5c	5c	5c	5c	5c
Tree 16, lot II...	2c	2c-3c	4c	4c-5c	5c-6c	5c	5c	6c	6c	6c
Tree 88, lot I...	2c	1c-2c	3c	3c-4c	4c	4c	4c	4c-5c	4c-5c	—

*Kernels having warm and cold tones are distinguished by "w" and "c" respectively.

color was noticeable after 1 week, and darkening then continued rather rapidly for 6 to 8 weeks. Thereafter, in most cases, color changes were not appreciable. In all cases kernels of lot II darkened more rapidly and reached a darker color than those of lot I. The color classification of the kernels involved in this study is presented in Table I.

There was some variation in the rate and degree of color change among the kernels from the various trees. The Thomas kernels were very responsive to delay in hulling. When nuts were hulled immediately, the kernels were light-colored and very attractive. After hulling was delayed 2 weeks, the kernels became somewhat dark and unattractive (Fig. 2). The color of kernels from tree 12 was less affected by delayed hulling than any tested. With this tree, the 15-week sample of lot I was approximately the same color as the 3-week samples from the Thomas trees. The behavior of the kernels from trees 13, 15, 16, and 88 was quite similar to the Thomas. All darkened noticeably after 1 week and continued to darken as the delay in hulling was prolonged.

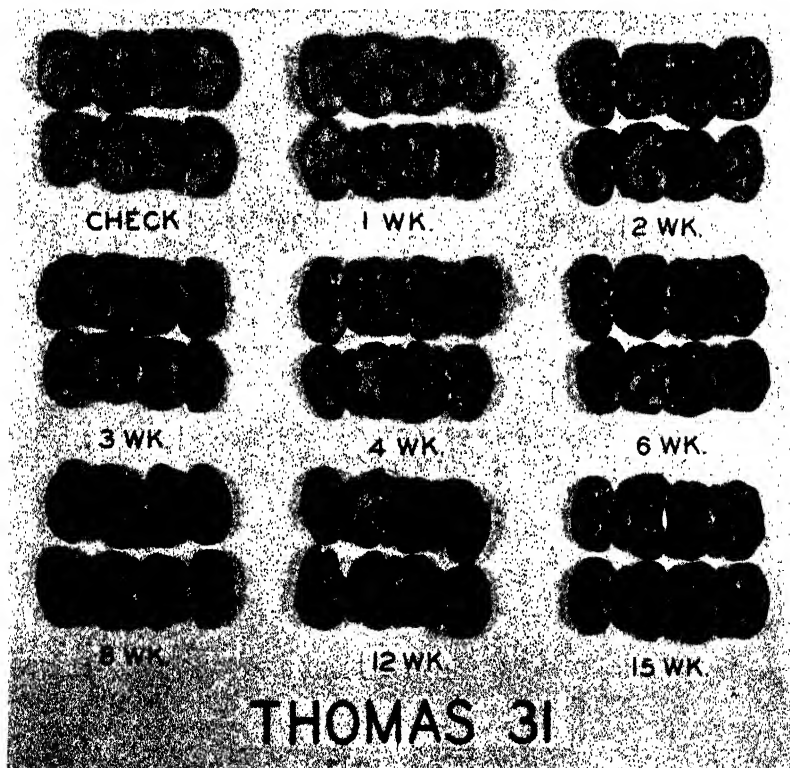


FIG. 2. Black walnut kernels from one of the Thomas trees used in this study. The *check* kernels are from walnuts hulled immediately after harvest. The rest of the samples (lot I) are from walnuts which were left unhulled outdoors for the time indicated.

Flavor of Kernels:—The kernels of the check samples from all the trees were very mild and pleasant in flavor. While testers did not uniformly recognize flavor differences between successive samples (for example, the check and 1-week, or 4-week and 6-week, when directly compared), all agreed that the kernels from walnuts remaining in the hull the shortest length of time were the mildest in flavor. When the check, 3-week, and 8-week samples from each tree were compared, all indicated that the check sample was the mildest, followed by the 3-week sample, with the 8-week sample the strongest.

DISCUSSION

It is apparent from the results of this study that the color of black walnut kernels is affected by the length of time the walnuts are allowed to remain unhulled. Kernels from nuts which remained unhulled for 1 week were noticeably darker than those hulled immediately, except with trees 12 and 88. With these two trees, the color did not become appreciably darker until the nuts remained unhulled for 2 weeks. The rapidity with which the kernels assume a dark color when unhulled indicates the necessity for immediate hulling (Fig. 2).

Of interest was the behavior of the kernels of lot II. These kernels darkened more rapidly and reached darker shades than lot I kernels. As the room in which the walnuts of lot II were stored was rather humid, the hulls remained moist for a longer period than did the hulls of the lot I walnuts. If the latter lot had been exposed to equally high humidity at the critical period of kernel color change, it is probable that there would have been little color difference between these two lots.

In all flavor tests personal prejudices at once become evident. However, the judges were instructed to rate the kernels on the basis of mildness alone, and it is felt that, in general, this was done. The effect of the hull on flavor was almost as pronounced as on color. When walnuts were hulled immediately after falling from the trees, the flavor was much milder than when hulling was delayed 3 weeks. The kernels of walnuts exposed for longer periods became strong and less palatable. The condition of the kernels was also affected by the treatment to which the walnuts were subjected. The check and 1-week kernels from all trees remained intact under continued handling, while the kernels from the remainder of the samples tended to break and lose their pellicles.

The kernels involved in this study were compared with kernels going to the market from commercial crackeries. Kernels from walnuts hulled within a week after harvest were much superior in color, quality, and flavor to the commercial kernels. It is apparent that the market is not receiving the best quality kernels because of lax handling methods following maturity. The results here presented indicate that those engaged in the cracking of black walnuts can materially improve the quality of their product by immediate hulling.

CONCLUSIONS

Both color and flavor of kernels were adversely affected by delay in hulling. Within certain limits, the change in color and flavor was

directly related to the length of time the nuts remained unhulled after maturity. With the trees used in this study it was possible to obtain light-colored, mild-flavored kernels by hulling walnuts within 7 days after harvest.

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A Method of Evaluating the Nuts of Black Walnut Varieties¹

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THE shelling of nuts of the eastern black walnut, *Juglans nigra* L., in the Tennessee Valley and adjacent territory is an industry of considerable importance to a certain portion of the rural population. It is estimated that in an average year about 7,000,000 pounds of nuts are shelled in the home and about 10,000,000 pounds are shelled by power equipment. Most of the kernels find a market in the ice cream and confectionary trade.

In order to provide this industry with nuts which can be more profitably handled than the average wild nuts, a series of variety test plantations were established to find varieties suitable for farm planting and top working. From among the large number of varieties which are on record (4), only a few of the most promising were selected for inclusion in these plantations. In the course of making this selection, the need was felt for a specialized, reasonably precise method of judging nut quality. This paper deals with the development of a method for judging nut quality where the commercial production of kernels by hand-shelling methods is contemplated.

General methods for judging black walnuts were proposed as early as 1914 (5) when a score card was devised. Bixby (1) revised the scoring system by introducing quantitative methods. Drake (3) proposed additional changes, basing the score on an ideal nut.² MacDaniels (6) reported a tentative schedule developed by a committee of the Northern Nut Growers Association, and after 2 years of testing the schedule,³ suggested certain modifications (7) MacDaniels deemed the schedule not entirely satisfactory and was hopeful of further improvement.

MacDaniels' scoring system provided the basis for developing the method herein reported. MacDaniel's system is extremely useful for general application and permits a worthy nut to be readily recognized. However, for the special purpose of evaluating a number of high-ranking varieties in terms of their relative value, other methods were needed.

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²Drake's system may be expressed as follows:

$$\frac{40g_1}{g} + \frac{100g}{w} + g + \frac{\text{color of kernel}}{(\text{up to 5 points})} + \frac{\text{flavor}}{(\text{up to 5 points})} = \text{score, where } w = \text{weight of nut in grams, } g = \text{weight of kernel in grams, } g_1 = \text{weight of kernel extracted at first crack.}$$

³MacDaniels' schedule may be expressed as follows:

$$w + \frac{200g_1}{w} + \frac{50g}{w} + \frac{Q}{10} - \frac{S}{2} - U - (0 \text{ to } 3 \text{ for dark color}) = \text{score, where } w = \text{weight of the nut in grams, } g = \text{weight of kernel in grams, } g_1 = \text{weight of kernels extracted at first crack, } Q = \text{number of quarters extracted from 25 nuts, } S = \text{number of shriveled nuts in 25, } U = \text{number of unfilled nuts in sample of sufficient size to yield 25 filled nuts.}$$

DISCUSSION OF NUT FEATURES AS THEY RELATE TO
THE EVALUATION OF VARIETIES

A method of ranking nut quality of the different varieties is needed wherein the evaluation is based on the income which might be derived from growing or processing the nuts. It appears that such a method must take into consideration the fact that the ultimate market product is in the form of kernels, and that the sale of unshelled nuts is negligible. The features which influence the attractiveness or sales appeal of the unshelled nut are of little importance. The likelihood of a future reversal of this condition is remote since the largest users of black walnut are bakers and confectioners who require the product in a readily usable form. Therefore, the features of a nut which affect its income-producing potentialities are those features which regulate the quantity and quality of the kernel, and the time required for its extraction. The desirable type of nut may be characterized as one from which a high proportion of tasty, attractive kernels may be extracted with low labor cost.

The various features of the nut which have been mentioned in previous work as having a bearing on its value are discussed below for the purpose of pointing out those which are relevant to the concept of nut value stated above:

Size is not subject to simple measurement and is of no direct consequence.

Weight is important since it determines the number of nuts which must be handled in shelling a given unit weight and thus influences the time required to complete the operation.

Form is of indirect importance in its effect on time required to shell the nut.

Color of nut has no bearing since only the kernels are marketed.

Thickness of shell is not easily measured and is so closely correlated with the easily measured kernel content, that it may be eliminated.

Thickness of partition may be an index of cracking quality but is not readily measurable, and may be eliminated in favor of a more direct measure of cracking quality.

Cracking quality is important in its bearing on the ease with which kernels may be extracted from the nut.

Number of quarters extracted is only an approximate measure of cracking quality. It has no other value in ranking selections since large pieces do not materially add to the market value of the kernels. Many consumers require the product in small pieces.

Kernel content, particularly the proportion easily extracted without recracking, is important in determining the yield of marketable kernel from a unit weight of nuts.

Color of kernel is dependent on manner of handling the nuts (2). Inherent varietal differences are generally insignificant compared to differences resulting from delayed hulling. Varieties which produce dark-colored kernels when hulled soon after maturity of the nut should be entirely discarded.

Plumpness of kernel is best measured in terms of kernel content.

Flavor is relatively unimportant. It is largely a matter of personal preference, is dependent to some extent on treatment of the nuts, and is not readily measured. However, varieties which possess a disagreeable flavor should be entirely discarded.

Kernel quality is of little consequence in the marketing of kernels. The degree of oiliness or starchiness has no bearing on the market value.

Husking quality may be eliminated from consideration as having no bearing on the yield of kernels.

It is concluded that *nut weight*, *kernel content*, and *cracking quality* are the only features which determine nut value. These three features are so related that it is difficult to assign properly weighted index numbers to each and, by adding the index numbers, arrive at

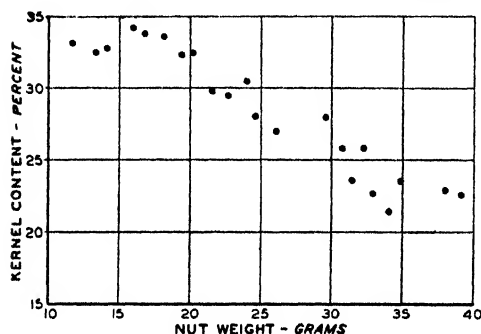


FIG. 1. Kernel content plotted against nut weight for the black walnut varieties which have the highest kernel content for their respective weights. These varieties are picked to represent the recorded extremes where both features are considered.

an empirical score which can be used to rank the varieties. This difficulty is largely due to the fact that nuts which have desirable *kernel content* are low in *weight* and heavier nuts are low in *kernel content*. This is shown in Fig. 1 where *kernel content* is plotted against *nut weight* for a number of varieties. The inverse relationship between *kernel content* and *nut weight* is modified by the independent variation of *cracking quality*. The relationship of all three factors

does not seem to be properly expressed by a simple additive score point system. Therefore, a direct system was evolved wherein nut value is expressed in terms of income-producing potentialities.

FORMULATION OF THE PROPOSED METHOD

In hand shelling, the most desirable type of nut is one which permits the highest hourly wage to be earned in shelling. It becomes necessary to formulate this principle in terms of the quantitative measures of the relevant nut features in order to obtain a single quantitative estimate of nut quality. Such an expression is formulated below.

Let it be assumed that the working speed and skill of a person (the worker) engaged in shelling can be held constant. Let the worker shell samples of nuts of different varieties and record the yield of marketable kernels and the time worked. Let the value of the unshelled nuts and the kernels be set by current market values. Then, earnings per hour for each lot of nuts is as follows:

$$\frac{\left\{ \begin{array}{l} \text{Pounds of} \\ \text{kernels} \\ \text{extracted} \end{array} \times \begin{array}{l} \text{Market} \\ \text{value per} \\ \text{pound} \end{array} \right\} - \begin{array}{l} \text{Market} \\ \text{value of} \\ \text{unshelled} \\ \text{nuts} \end{array}}{\text{Hours of labor}} = \text{earnings per hour}$$

A convenient form of this equation, particularly useful in calculating earnings where small samples are tested is:

$$.0794(pK-N) \frac{w}{T} = e$$

.0794 = a constant⁴

$$p = \frac{\text{weight of kernels recovered} \times 100}{\text{weight of nuts shelled}}$$

K = market value of kernels in dollars per pound

N = market value of unshelled nuts in dollars per 100 pounds

w = weight of average nut, in grams

T = average time required to shell one nut, in seconds

e = earnings in dollars per hour

The comparison of *earnings per hour* will permit the ranking of the different varieties. Although market values of nuts and kernels are subject to change, and therefore the calculated *earnings per hour* of a given lot of nuts may be in error, the relative position of the lot among others in the ranking will be unchanged. In this method, *cracking quality* affects earnings in terms of the time required to shell one nut, *weight* is accounted for by the number of nuts which must be handled to shell a 100-pound lot, and *kernel content* influences the yield of marketable kernels.

ERRORS OF ESTIMATION IN THE MEASUREMENT OF NUT FEATURES

In the proposed scoring method the readily measurable nut features, *weight*, *kernel content*, and *cracking quality* are needed in calculating the score. The measurement of these features is subject to certain errors of estimation, and it is important to reduce these

$$\begin{aligned} & \frac{pK-N}{\text{Hours of labor}} = e; \\ \text{and since } \left(\frac{\text{hours of}}{\text{labor}} \right) &= \left(\frac{\text{number of nuts}}{\text{per 100 pounds}} \right) \times \left(\frac{\text{shelling time of}}{\text{one nut in seconds}} \right) \\ &= \frac{\text{grams per 100 pounds}}{45359.2} \times \frac{\text{seconds per hour}}{3600} \\ &= \frac{w}{45359.2} \cdot \frac{3600}{T} \\ \text{therefore: } \frac{3600}{45359.2} (pK-N) \frac{w}{T} &= .0794 (pK-N) \frac{w}{T} = e \end{aligned}$$

errors to a practical minimum. Therefore, studies were made of some of the sources of variation and error.

Sampling Variance:—In order to obtain information on the size requirements of nut samples, the within-sample variance of nuts from a given tree in a given crop year was determined for several varieties by taking nuts at random from lots which were representative of the whole crop. Six lots of nuts of the 1938 crop were obtained from individual trees. Each lot was well mixed before the samples were drawn from it. *Nut weight* and *kernel content* were determined by cracking and weighing each nut separately. The mean and the variance were computed according to standard statistical methods.

Table I presents the data obtained from this study. It is estimated from the data that samples of 25 nuts will usually provide estimates of sufficient reliability to distinguish between sample means which differ by only 1 gram in weight or 1 per cent in kernel content. This seems to be satisfactory for preliminary evaluation of selections although, for precise tests such as might be made with nuts grown in variety test plots, samples of 100 nuts would probably be wanted. Great care should be exercised to obtain representative lots and to draw the sample nuts at random.

TABLE I—SAMPLE VARIANCE OF NUT WEIGHT AND KERNEL CONTENT OF SEVERAL BLACK WALNUT VARIETIES (1938 CROP)

Variety	Source	Number of Nuts in Sample	Nut Weight (Grams)		Kernel Content (Per Cent)	
			Mean	Sample Variance	Mean	Sample Variance
Edras.....	Arkansas	56	17.11	4.17	30.25	4.41
Seedling 664.....	Tennessee	45	17.30	4.05	20.58	1.16
Mintle.....	Arkansas	66	14.98	1.46	29.41	1.60
Monterey.....	Pennsylvania	60	23.20	4.26	28.54	2.82
Ohio.....	Virginia	62	19.68	2.31	28.62	2.83
Ten Eyck.....	Pennsylvania	50	16.98	2.09	29.14	3.73

Pooled variance of nut weight is 2.966 grams; of kernel content is 2.761 per cent.

Where sample number = 25, and $P = .05$, the minimum significant differences are: nut weight, ± 1.01 grams; kernel content, $\pm .97$ per cent.

Moisture Content:—Studies were made of the effect of moisture differences in introducing errors in the measurement of *nut weight* and *kernel content*. The average moisture content of stored nut samples was first determined. The samples were obtained through correspondence from 63 sources. No control had been exercised over the way in which the nuts were harvested and cured prior to being received. However, all samples were stored together in a well-ventilated, unheated room until shelled. Moisture content⁵ was determined separately for the kernels and shells by oven drying. The average moisture content of kernels was 5.1 per cent, the individual samples ranged from 1.01 to 12.77 per cent. The average moisture content of shells was 11.43 per cent, the range was from 5.26 to 18.58 per cent. In the individual samples, the ratio of kernel moisture to shell moisture was

$$\text{Moisture content} = \frac{\text{Loss in weight}}{\text{Dry weight}}$$

somewhat variable but always the shells contained more moisture than the kernels. The average moisture content of 5.1 per cent for kernels and 11.4 per cent for shells was considered the best estimate of the typical condition of sample nuts in these studies. These averages were used as the base moisture content in adjusting for differences in *nut weight* and *kernel content*.

In Table II, data are presented to show the magnitude of the adjustments in *nut weight* and *kernel content* which result from adjusting the data on 16 samples to a common base moisture content. It will be noted that the moisture content of the different samples varied considerably, and that this range is probably great enough to provide a fair illustration of the usual moisture condition of nut samples. These data indicate that the errors introduced by ignoring moisture are of the same order as errors of estimation due to sample size where only 25-nut samples are used. Thus, for precise tests,

TABLE II.—THE EFFECT OF MOISTURE CONTENT ON THE MEASUREMENT OF NUT WEIGHT AND KERNEL CONTENT (1940 CROP)

Source	Moisture Content as Sampled		Nut Weight			Kernel Content		
	Kernel (Per Cent)	Shell (Per Cent)	As Sampled (Grams)	Adjusted* (Grams)	Difference (Grams)	As Sampled (Per Cent)	Adjusted* (Per Cent)	Difference (Per Cent)
<i>Ohio</i>								
Absher, Ky.....	5.97	13.89	14.4	14.1	-.3	27.4	27.6	+.2
Center Point, Iowa	8.20	10.58	15.7	15.6	-.1	30.3	29.6	-.7
Fayetteville, Ark...	2.82	8.94	18.4	18.8	+.4	29.2	29.2	0
Forest Hill, Md....	2.30	10.22	16.7	17.0	+.3	27.1	27.4	+.3
Lancaster, Pa.....	12.77	16.85	16.3	15.4	-.9	28.5	28.0	-.5
Lancaster, Pa.....	4.41	9.84	16.6	16.8	+.2	29.4	29.2	-.2
Rockport, Ind.....	5.00	12.39	17.2	17.1	-.1	30.2	30.4	+.2
Worton, Md.....	11.32	18.58	14.6	13.7	-.9	31.4	31.5	+.1
<i>Thomas</i>								
Absher, Ky.....	4.17	12.00	19.8	19.8	0	26.6	26.9	+.3
Center Point, Iowa	6.38	11.11	19.9	19.9	0	25.7	25.4	-.3
Forest Hill, Md....	1.01	7.30	21.3	22.1	-.2	24.4	24.5	+.1
Lancaster, Pa.....	7.84	12.00	18.1	17.9	-.2	27.8	27.4	-.4
Petersburg, Va.....	3.45	11.64	17.8	17.8	0	27.7	28.1	+.4
Rockport, Ind.....	2.41	9.65	21.3	22.0	+.7	25.6	25.4	-.2
Worton, Md.....	2.88	11.11	19.2	19.4	+.2	29.5	29.9	+.4
Yellow House, Pa...	4.54	11.93	15.9	15.9	0	28.2	28.4	+.2

*Adjusted to the base moisture content of 5.1 per cent for kernels, and 11.4 per cent for shells.

moisture content should be determined and the nut measurements adjusted to a common base moisture content. For preliminary and rapid tests of nut quality, moisture content may be ignored so long as the sample is well cured by being hulled and then air dried for a period of about 2 months.

Site.—In order to study the differences in nut development which may result from environmental differences, studies were made of a number of grafted trees of the Ohio and Thomas varieties. Nut samples from eight sources were secured from individual trees of each variety in the fall of 1940. *Nut weight* and *kernel content* were determined from samples of 25 or more nuts in each case.

The data are presented in Table II (along with the data on moisture content). An examination of the data in the *adjusted nut weight* and *adjusted kernel content* columns shows a range of differences in the Ohio nut from various sources of 5.1 grams in *weight* and 4.1 per cent in *kernel content*, and in the Thomas nut from various sources of 6.2 grams and 5.4 per cent. These are considerably in excess of the expected error due to sample size. These variations in the character of the nuts may be attributed to differences in the climate and soil factors where they were grown. To deal effectively with this source of variation, it would be desirable to obtain nut samples from variety test plantations located in the region where the commercial planting of the species is contemplated.

Crop Year.—Another source of error is the year-to-year difference in nut development. Studies of these differences were started several years ago, but the difficulties of getting samples from the same tree year after year were so great that only a few were obtained. However, samples of the crop from seven trees for two crop years were examined. *Nut weight* and *kernel content* were determined from samples of 25 or more nuts in each case.

Data showing differences in the nut development of identical trees in different years are presented in Table III. It will be noted that the between-season difference in nut development is appreciable. The recognition of this source of error makes evident the necessity of repeated examination of nut crops over a span of years.

TABLE III.—OBSERVED DIFFERENCES IN NUT DEVELOPMENT OF IDENTICAL TREES IN DIFFERENT YEARS

Variety	Mean Nut Weight (Grams)				Maximum Observed Difference (Grams)	Mean Kernel Content (Per Cent)				Maximum Observed Difference (Per Cent)
	1937	1938	1939	1940		1937	1938	1939	1940	
Aygarn.....	.....	.....	28.4	25.5	2.9	.....	.....	20.9	23.0	2.1
Benge.....	28.4	.....	.....	24.7	3.7	22.1	.....	.....	17.9	4.2
Calhoun										
No. 1.....	.....	.....	15.8	13.3	2.5	.....	.....	28.9	27.2	1.7
Henegar.....	.....	.....	21.8	22.3	.5	.....	.....	22.0	19.8	2.2
Huber.....	14.1	.....	.....	18.4	4.3	32.8	.....	.....	30.1	2.7
Monterey.....	.....	23.2	.....	21.8	1.4	.....	28.5	.....	24.6	3.9
Snyder.....	.....	16.4	21.3	17.1	4.9	.....	28.0	24.7	26.2	3.3

Worker.—The measurement of *cracking quality*, expressed in terms of the average time required to shell one nut, is subject to errors of estimation due to the differences in speed and skill of different workers and to differences in the performance of the same worker at different times. Errors of this sort can be accounted for and eliminated from influencing the relative ranking of various test lots of nuts by setting up a system of judging in which several workers make replicated tests.

APPLICATION OF THE PROPOSED METHOD

A series of tests were made in which the nuts of 15 varieties were evaluated according to the proposed method. Consideration was given to the need for reducing the errors of estimation. The varieties

chosen for these tests were picked from available lots of nuts to include some of the better kinds as well as some of doubtful value. All nuts were from the 1940 crop.

In running the test, four workers shelled sampling units of 10 nuts of each variety and the whole series was repeated, making a total of eight sampling units or 80 nuts per variety. The order of shelling of the samples was assigned at random, separately for each worker and separately for the first and second series. Nuts were shelled with the aid of a hand-operated cracker⁶ and re-cracked with hammer and anvil where necessary. Time intervals were measured with stop watches, and weights of marketable kernels were obtained after discarding all crumbs which passed through a 6-mesh-per-inch sieve. The average earnings per hour were calculated for each sample

$$\text{according to } .0794(pK-N) \frac{W}{T} = e$$

by setting the values of K at \$25 and N at \$2.00, and these data are presented in Table IV. The data were subjected to analysis of vari-

TABLE IV THE RESULTS OF EVALUATING FIFTEEN NUT SAMPLES BY THE PROPOSED METHOD

Variety	Marketable Kernel Content ±0.75* (Per Cent)	Earnings per Hour for Hand Shelling $.0794(pK-N) \frac{W}{T} = e$ ±0.021* (Dollars)
Norris.....	28.9	.279
Ohio.....	28.3	.245
Horton.....	28.5	.233
Mintle.....	29.5	.231
Thomas (Tenn.).....	28.8	.228
Cochrane.....	33.1	.219
Ten Eyck.....	30.7	.203
Edras.....	30.8	.200
Thomas (Ark.).....	24.8	.184
Powell.....	25.7	.193
Seedling 3H-16.....	26.0	.170
Speer.....	19.2	.166
Huber.....	28.9	.138
Rohwer.....	25.9	.132
Seedling 3H-25.....	20.0	.120

*Minimum significant differences between varieties at the .05 level of probability.

ance and highly significant between-variety differences were found. It was also evident that the four workers performed with differing skill. Average earnings per hour per worker were 21.7 cents, 20.7 cents, 19.2 cents and 17.1 cents with minimum significant differences of ±1.98 cents. There were indications that some of the workers favored certain selections, and that all workers performed better in the second series than in the first. However, the design of the test took proper account of these conditions and provided a satisfactory estimate of nut quality.

This method of evaluating quality of nut samples served the pur-

⁶The cracker used was of the type manufactured by J. W. Hershey, Downingtown, Pennsylvania.

pose for which it was designed, and it may have wider application in other black walnut studies. It provides an estimate of nut quality with reasonable precision along with an estimate of error. The so-called human equation in judging is reduced by making all relevant features subject to measurement and by replicating the workers and the sampling units. Nut quality is expressed in terms of dollars so that differences in quality assume their real value (or nearly so). This method does not obviate the necessity for making tests over a span of years and with nuts from grafted trees in different locations in order to evaluate nut quality of a variety. It does not replace MacDaniels' (7) system since it is not designed for the judging of isolated samples by workers in different places.

SUMMARY

1. A newly developed method of judging nuts of black walnut varieties on the basis of their income-producing potentialities is presented.

2. Data are presented to show differences in the nut development of a given tree during different years, and to show the necessity of making repeated nut tests over a span of years.

3. Data are presented to show within-variety differences in nut development observed in trees from several locations, and to show the desirability of establishing variety-test plantations.

4. The effect of moisture content in introducing errors in the measurement of *nut weight* and *kernel content* was examined, and it was concluded that, in preliminary work, moisture content need not be determined if the nut is reasonably well cured, but for more precise work, such as the closer evaluation of the more promising varieties, moisture content should be determined and data should be adjusted to a common base moisture content.

5. It was concluded that 25 nuts drawn at random from a representative lot constitute an adequate sample, except where very precise comparisons are required.

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Seed Production and Seedling Yields of Some Citrus Varieties of Possible Value for Rootstock Purposes¹

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STUDIES in the past 20 or 30 years on the usefulness of various citrus rootstocks have concerned mostly congeniality with the scion variety, resistance to diseases, and adaptability to soil and climate. While these factors are important, there are two other factors important from the commercial standpoint on which little has been published. A variety may rate best in all three of the above factors and still be of little practical use as a stock because of low seed production or because of slow development of the seedlings. A brief discussion is given by Hume (1) in which he estimates the average seed yield per fruit as follows: sour orange, 20; grapefruit, 55; sweet orange, 18; rough lemon, 20; and trifoliate, 25 seeds. No records seem to be available in literature on seed production.

From the propagator's standpoint the availability of seed for rootstocks is an important consideration. For example, the Morton citrange is an excellent stock for satsumas and the Navel orange but it is so low in seed production that it cannot be used profitably.

SEED PRODUCTION

Through the cooperation of Dr. W. T. Swingle and others in the United States Department of Agriculture, a number of varieties of citranges and other citrus hybrids were planted at Winter Haven, Texas, in 1932 and later years. Some varieties were obtained locally or from commercial nurseries.

In 1939, many of these were in full bearing. Descriptive notes including records on the number of seeds per fruit were taken. These were based on 10 fruits from each variety selected at random. It is realized that this number is rather small for accuracy but interest was chiefly in obtaining a comparative rating. In 3 years records summarized in Table I it will be noted that most of the varieties were fairly consistent. A notable exception is Savage citrange which dropped from good seed yields in 1939 and 1940 to almost none in 1941. A record from 25 fruits of Carrizo citrange in 1941 gave 519 seeds or an average of 20.8 as compared with 22.7 in Table I. It seems that 10 fruits served the purpose of the study fairly well.

The fruits were weighed in grams and from this the number of seeds per pound of fruit was calculated. From this an estimation of seed yield per tree can be made (Table I). The trifoliate orange leads in seeds per fruit with an average of 45.9 for the 3 years. At the other extreme is citradia which averages only one seed in five fruits.

Based on the estimated yield per tree the more promising varieties so far as quantity of seed is concerned are trifoliate orange, Carrizo citrange, Changsha tangerine, citrumelo, Swatow tangerine, Citranged-

¹Technical Contribution No. 711, Texas Agricultural Experiment Station.

TABLE I—SEED YIELDS OF CITRUS VARIETIES

Variety	Source	Seeds Per Fruit			Weight of Fruits				Average Number Seed Per Pound Fruit	Estimated Index Yield Per Tree		
		(Average 10 Fruit)			(10 Fruits, Grams)					Fruit Pounds	Number Seed	
		3-Year Average			Average Per Fruit							
		1939	1940	1941	1939	1940	1941	(Grams)				(Pounds)
Calamondin.....	Commercial	3.3	4.0	5.3	4.2	113	250	205	18.9	0.04	105	10,500
Citradia.....	CPB50049A	0.2	0.1	0.3	0.2	680	1,023	604	76.9	0.17	200	200
Citrange, Carrizo.....	CPB45019B	21.1	16.9	22.7	20.1	964	956	836	91.9	0.20	600	60,600
Citrange, Cuna.....	CPB1418ADC	0.4	3.1	2.7	2.1	1,134	1,340	1,000	115.8	0.26	300	2,400
Citrange, Morton.....	TS15138	0.9	0.9	1.4	1.6	2,552	2,783	2,297	254.4	0.56	500	1,500
Citrange, Rusk.....	TS15139	2.6	3.3	4.4	3.4	680	897	876	81.8	0.18	500	9,500
Citrange, Rustic.....	CPB12766	3.0	6.0	1.6	3.5	1,588	1,813	1,284	156.2	0.34	10	3,500
Citrange, Savage.....	CPB12769	15.8	10.8	0.4	9.0	1,776	1,852	1,571	173.3	0.38	24	350
Citrange.....	TS15137	8.6	7.7	2.4	6.2	992	858	778	87.6	0.19	33	400
Citrange, Glen.....	CPB48045E	5.8	8.6	7.6	7.3	170	245	216	21.0	0.05	146	13,200
Citrangequat, Thomas.....	CPB48010	6.8	4.3	4.7	5.3	312	515	475	43.4	0.10	53	21,900
Citrumelo.....	CPB4554C	18.2	16.6	14.1	16.3	1,021	730	869	87.3	0.19	86	15,900
Eremocitrus pectinifera.....	CPB10280	39.5	3.3	6.0	40.6†	3,317	256	223	24.0	0.05	92	34,400
Grapefruit, Duncan.....	Commercial	3.3	—	—	3.3†	3,629	—	—	359.4†	0.79	51	17,850
Grapefruit, Garner.....	Commercial	8.0	—	—	8.0†	1,871	—	—	182.9†	0.80	4	350
Lemon, Meyer.....	Commercial	6.2	—	—	6.2†	170	—	—	17.0†	0.41	20	6,000
Limequat, seedling.....	Commercial	4.7	—	—	4.7†	312	—	—	31.2†	0.04	155	15,500
Limequat, Lakeland.....	TS29040	20.9	—	—	16.0†	1,106	—	—	53.4†	0.07	100	6,700
Orange, Chinotto.....	TS23165	13.4	31.7	11.1	16.0†	619	449	449	53.4†	0.12	133	150
Orange, Kansu.....	CPB11298	27.5	35.0	35.0	31.4	2,033	1,192	1,444	144.4	0.32	98	100
Orange, Louisiana Sweet.....	Commercial	20.6	32.7	19.3	16.3†	1,492	1,492	1,535.5†	153.5†	0.34	48	350*
Orange, Sour.....	Commercial	24.8	32.7	29.1	27.5	1,818	2,332	1,579	193.1	0.43	64	200
Tangerine, Changsha.....	CPB10071P	5.2	14.2	30.5	23.2	737	1,305	1,843	97.0	0.21	110	12,800
Tangerine, Clementine.....	Commercial	20.2	—	—	5.2†	765	1,395	869	76.5†	0.17	30	400
Tangerine, Swatow.....	Commercial	49.3	54.7	33.8	16.4	255	1,276	1,357	134.3	0.30	55	9,000
Trifoliolate.....	Commercial	—	—	—	45.9	1,276	1,395	494	33.8	0.07	656	22,000

*Based on actual measured yields.

†One year only.

‡Two years only.

in, Chinotto, Duncan grapefruit, Louisiana Sweet orange, citrangequat, limequat (T.S. 28040), and sour orange.

SEEDLING YIELDS

The seed produced is valuable only if a high proportion of usable seedlings can be obtained in a short time. In 1940, ten varieties were planted in the field, 300 seeds of each, to try to get an idea of the seedling development. Germination was reasonably good but sparrows destroyed the newly emerged seedlings so no record of comparative yields could be made. Of the seedlings that survived citrumelo and trifoliata orange gave the highest per cent of seedlings suitable for budding in the fall.

In order to protect from sparrows in 1941 the 300 seeds of each variety were planted in flats in a lathhouse and lined out in nursery rows when $1\frac{1}{2}$ to 2 inches high. A record on germination was secured in the flats. Since a few of the seedlings were not lined out due to lack of time from other work, it was necessary to calculate the number of usable seedlings from 300 seeds from this germination record.

On October 15, measurements at 2 inches above the ground level were made with a caliper set at 5 millimeters. All seedlings with a diameter above this were considered satisfactory for budding and therefore "usable". This is a good date for budding citrus in South Texas since the bark will still slip and the bud remains dormant until the following spring. Hence the "usable" seedlings on this date is a valuable criterion for nurserymen in South Texas.

Only 11 varieties were included in this test and of these the citranges made the best growth during the summer (Table II). Carrizo citrange, trifoliata and sour orange were the best in yield of usable seedlings in this test. Swatow gave as good a germination but grew more slowly.

TABLE II—SEEDLING YIELDS FROM 300 SEEDS (1941)

Variety	Total Seedlings		Average Seedling Height Oct. 15 (Ins.)	Usable Oct. 15		Calculated Number Usable From 300 Seeds†
	In Spring	Lined Out		No.*	Per Cent	
Citrang, Carrizo.....	334	294	39.9	278	95	317
Citrang, Savage.....	97	65	31.1	60	92	89
Citrang, 15137.....	101	61	46.0	55	90	91
Citrangedin.....	68	66	18.0	2	3	2
Citrangquat.....	50	25	27.1	11	44	26
Citrumelo.....	61	58	32.2	38	66	40
Orange, Chinotto.....	68	12	14.0	0	0	0
Orange, Sour.....	232	206	28.9	118	57	132
Tangerine, Changsha.....	126	36	29.3	15	42	53
Tangerine, Swatow.....	266	221	24.2	74	33	88
Trifoliata.....	251	221	23.4	148	67	168

*Usable above 5 millimeter caliper at 2 inches above ground.

†Based on original germinated seedlings had they all been lined out.

Citrangedin and Chinotto were very slow in development. By way of explanation, citrus seeds commonly have more than one embryo and hence the yield of seedlings may be greater than the original number of seeds planted.

On the basis of these results, Carrizo citrange seems to be a promis-

ing variety of citrus rootstock for the Winter Garden area of Texas. It has a high yield of fruit and consistently good seed production. Germination and yield of usable seedlings is excellent. Carrizo was received under number CPB 45019B and was named "Carrizo" by T. Ralph Robinson and H. P. Traub (2) in 1939. Preliminary tests indicate good compatibility with Kawano Kase and Owari satsuma, Marsh grapefruit and Meyer lemon.

It should be emphasized that the best seedling producers are not here recommended for use as rootstocks but only suggested for trial as they obviously have a large practical advantage in the nursery over the other types. Final recommendations will, of course, depend on the behavior of these stocks over a number of years with the commercial varieties of citrus in the orchard.

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Vegetative Responses of the Elberta Peach on Lovell and Shalil Rootstocks to High Chloride and Sulfate Solutions

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FIELD observations have indicated that some rootstocks are superior to others in promoting good growth of the scion. Hutchins (3) found that the Shalil peach rootstock promoted vigorous growth, the trees (Early Hiley) on that rootstock being "among the most vigorous and productive in the orchard" where nine different rootstocks were under test. He also found complete resistance to root-knot, and Tufts and Day (2, 4, 5) obtained similar results on nematode resistance with Shalil in California. Chandler (1) has noted the tolerance of peaches on Davidiana rootstock to saline conditions, but that variety has not been a desirable one because of lack of vigor.

Owing to the extensive use of the Lovell variety as a rootstock and the favorable characteristics reported for the Shalil, they were selected to test the effects of chloride and sulfate salts on peaches. The Elberta variety was used as the scion.

MATERIALS AND METHODS

Elberta peach trees on Lovell and Shalil rootstocks have been grown in sand culture under differential salt treatments since the spring of 1940. Seventy-two yearling trees were planted in 4-gallon glazed earthenware containers which were sunk in the soil to avoid the inhibiting effect of high temperature on the root systems. The trees were randomized in blocks of four and maintained in this design until February, 1941, when they were transplanted to sand tanks which were large enough (5 feet by 10 feet by 6 feet) to accommodate four trees without excessive crowding (Fig. 1).

The large sand culture tanks are arranged in a block of three rows, six per row. The experimental design was so planned that each row of tanks contained all six treatments with the treatments randomized in the rows. Two trees on each rootstock were arranged in each tank so that a Shalil and a Lovell rootstock occupied opposite corners with the others in the intermediate positions. At the conclusion of the 1941 growing season, the intermediate trees were harvested and data obtained with respect to their vegetative responses. The remaining trees are being carried on so that studies of fruiting responses can be made.

Each tank has its own reservoir with a capacity of 4,500 liters of solution which is circulated to the sand cultures by electrically driven pumps controlled by a time clock. The pumps deliver sufficient water at one irrigation to completely flood the surface thus preventing any unequal accumulation of salts in the upper layers of sand. The frequency of irrigation was determined by the weather and the vegetative status of the trees. During mid-summer, the irrigations were at 3 hour intervals from 6 a.m. to 6 p.m. with one at midnight.



Fig. 1. General view of the sand culture tanks showing the arrangement of the trees and their growth status on April 8, 1941.

Six solutions were used: 1, the control or basic nutrient solution; 2, 3, and 4, the basic nutrient solution plus 10, 40, and 80 milliequivalents of chloride per liter; and 5, and 6, the basic nutrient solution plus 80 and 160 milliequivalents of sulfate per liter. The cations of the added salts were supplied as Na, 65 per cent; Mg, 25 per cent; and Ca, 10 per cent. Solutions were brought up to volume twice weekly and the pH adjusted to 6.5 using HNO_3 .

The composition of the four-salt nutrient solution, expressed in millimoles per liter, was $\text{Ca}(\text{NO}_3)_2$, 1.0; KNO_3 , 2.0; MgSO_4 , 1.2; and KH_2PO_4 , 0.2. The essential micro-elements were added, and iron was supplied as magnetite, 0.3 per cent by weight, mixed with the sand. Table I shows the Cl or SO_4 content of the solutions expressed in milliequivalents and parts per million, and the average osmotic concentration of each.

CARE OF TREES

During the dormant season, and prior to transplanting into the

TABLE I—COMPOSITION OF SOLUTIONS USED

Solution	Total Cl or SO_4		Osmotic Concentration Atm.*
	M e/l	P p m	
Control	1 Cl 3 SO_4	36 142	0.40
Low Cl	10 Cl	355	0.73
Intermediate Cl	40 Cl	1418	1.95
High Cl	80 Cl	2836	3.36
Intermediate SO_4	80 SO_4	3842	2.21
High SO_4	160 SO_4	7684	3.61

*Average of 15 determinations.

large sand tanks, all of the trees were uniformly pruned so as to leave four scaffold branches with two or three laterals on each one. Measurements were taken of the height and diameter of the main axis and the total length of the branches to serve as a basis for the determination of total growth during the 1941 season.

In March, about 10 days ahead of the expected opening of the buds, all trees were sprayed with dinitrophenol using a power spray rig. No difficulty was experienced with delayed foliation; but, owing to the fact that no extra trees were available to serve as controls, it is not possible to state to what extent this was due to the application of the spray. It seems probable that the season was a favorable one for Elberta peaches as there was relatively little trouble encountered in the southern California area with this variety or with Sims, while considerable delayed foliation occurred with the Lovell, Hale and Tuscan varieties. No spray was applied during the spring of 1942. There was some delayed foliation which was most pronounced on the trees under the high sulfate treatments.

GROWTH DATA

Following transplanting in February 1941, the vegetative buds began to expand and show color the first week in March, and subsequent growth and development was rapid. Owing to the procedure of adjusting the pH with HNO_3 , the average concentration of NO_3 in the solutions was approximately 5.5 milliequivalents per liter (341 parts per million) during the growing season of 1941. On this luxury consumption basis with respect to nitrate, the trees made better than normal growth under the control treatment.

The diameter of each tree was measured at regular intervals to determine the rate of secondary thickening. There were highly significant differences in cambial activity between the trees under the high chloride and sulfate treatments and those in control tanks. Table II

TABLE II—GROWTH RESPONSES OF ELBERTA PEACH ON LOVELL AND SHALIL ROOTSTOCKS

Treatment	Diameter (Centimeters)		Linear Growth (Meters)		Weight (Kilograms)		Volume (Liters)	
	Lovell	Shalil	Lovell	Shalil	Lovell	Shalil	Lovell	Shalil
Control.....	6.0	6.5	197	220	8.24	10.00	8.45	10.12
10 m.e. $\text{Cl}^-/\text{l.}$	5.9	6.7	222	228	8.54	11.00	8.85	10.91
40 m.e. $\text{Cl}^-/\text{l.}$	6.0	5.7	206	166	8.19	7.04	8.12	6.99
80 m.e. $\text{Cl}^-/\text{l.}$	4.6	4.9	125	103	4.74	4.26	4.84	4.48
80 m.e. $\text{SO}_4^{--}/\text{l.}$	5.9	6.2	214	218	8.48	8.69	8.56	8.78
160 m.e. $\text{SO}_4^{--}/\text{l.}$	4.3	4.4	107	106	3.85	3.97	3.87	3.90

shows the average diameter of the trees when harvested at the conclusion of the 1941 growing season. As indicated in this table, high concentrations of either chloride or sulfate salts result in a marked reduction in the diameter of the stem. With respect to the differential response of the rootstocks, the Shalil promoted greater secondary thickening under the control, low chloride, and intermediate sulfate treatments while trees on the Lovell rootstock developed more rapidly

under the intermediate chloride treatment. No difference due to rootstock was observed at the high chloride level.

The vegetative response in terms of the total linear growth of the tops is shown in Table II. This shows that the high concentrations of salt have resulted in a very marked reduction in linear growth, and that this inhibition is approximately the same at the high chloride and sulfate levels. The reduction under the intermediate sulfate treatment was not as marked as at the intermediate chloride level and there was slightly more linear growth at the low chloride level than under the control treatment. The Shalil rootstock promoted slightly superior growth than the Lovell at the control, low chloride and intermediate sulfate levels. At the intermediate and high chloride levels, the Lovell rootstock produced considerably more growth. There was no significant difference between rootstocks at the high sulfate level.

The data for weight and volume of tops, shown in Table II present the same picture with respect to the vegetative responses. On the basis of diameter, linear growth, weight, and volume of tops, the data indicate that the high chloride and sulfate treatments result in essentially the same amount of growth depression; that there is somewhat less depression at the intermediate sulfate level than at the intermediate chloride level; and that the growth at the lowest chloride level is slightly more than that of control trees. On the basis of influence of the rootstock, it would appear that the Shalil promotes better vegetative development at low salt concentrations; but that with the high chloride treatments a better response is made by trees on the Lovell rootstock.

FOLIAR DEVELOPMENT

Delayed foliation occurs frequently in the peach districts of Southern California owing presumably to the mild winters and high light intensity. As noted above, no serious prolonged dormancy was encountered at the beginning of the 1941 season while it was fairly pronounced in 1942. The application of dinitrophenol spray may have promoted normal foliation in 1941, but there was little difficulty on that score with Elberta in the Los Angeles area regardless of spray treatment; whereas in 1942 some delayed foliation occurred. It is not unlikely that light as well as temperature affects foliar development; but, with respect to the former, it is not clear to what extent a so-called light effect may be a temperature relation. Without attempting to draw any conclusion, and bearing in mind the application of the dinitrophenol spray in 1941, it may be recorded that at Riverside, California there were 461 hours below 45 degrees F in 1941 and 724 hours in 1942. The total hours of sunshine September 15, 1940, to March 31, 1941 was 1,342, and 1,442 for the same period in 1941-42. The total daily radiation for these periods was 59,659 gram calories per square centimeter in 1940-41 and 66,128 in 1941-42.

In the spring of 1941, the vegetative buds developed earliest under the chloride treatments, but this initial difference was equalized within a week after the first buds showed color; and, subsequently, there was a better development of buds at the control and low chloride levels.

In all treatments, the vegetative buds of trees on Shalil rootstocks opened earlier than those on Lovell. There was a lag of 4 to 5 days on the part of the latter which was evident over a period of 2 weeks. In 1942, the vegetative buds appeared earliest on trees having the high chloride treatment, followed by the intermediate chloride and then the high sulfate treatment. The lag of the low salt and control trees was much more pronounced than in 1941, as was the earlier response of the trees on Shalil rootstock.

SYMPTOMS OF SALT INJURY

Following the emergence of the leaves in March 1941, definite symptoms of leaf injury were soon evident in the high and intermediate chloride treatments. By April, the leaves of trees under the high chloride treatment were showing marked chlorosis, tip and marginal burning, many leaves were dying, and there was considerable abscission. There was some die-back of small branches on the high sulfate and chloride trees, this being more pronounced in the former in the 1941 season. Leaves of trees having the intermediate chloride treatment showed some tip burn. At both high and intermediate chloride levels, the symptoms of leaf injury were more pronounced on trees grown on the Shalil rootstock.

Similar but more severe leaf symptoms were observed in the spring of 1942 resulting in complete defoliation of the high chloride trees, and marked chlorosis and burning of the leaves of the intermediate chloride trees. The leaves of the high sulfate trees on Shalil rootstock also developed extensive marginal burning and there was pronounced defoliation. Die-back was very severe at the high chloride levels with practically all small branches showing severe injury extending for several inches from the tip. To a lesser degree, similar injury was observed with the intermediate chloride treatment. The severity of symptoms was more pronounced with the trees on Shalil than on Lovell rootstock in all cases. In both 1941 and 1942, the severity of the leaf symptoms was more pronounced at the beginning of the growing season than later on. As the season progressed, the new leaves were less chlorotic and there was a reduction in the amount of tip and marginal burning. By mid-season of 1941, it was difficult to find leaves with severe symptoms.

MORTALITY

On the basis of preliminary trials with Lovell and Shalil seedlings, it was expected that the high chloride and sulfate treatments would induce pronounced growth depression accompanied by severe symptoms, and that some of the trees would ultimately die. No mortality was experienced during the 1940 season, while the young trees were in pots; but the trees were only under full salt treatment from July 12 on, having been supplied with the basic nutrient solution prior to that date. Early in the 1941 season, it became evident that the development of the trees was severely inhibited by the high chloride treatment. By the latter part of May, 8 of the 12 trees under this treatment were dead. Four of these were Shalil and four Lovell so that there was no

indication of the relative tolerance of the two rootstocks. It was possible to replace two of the dead trees with others that had been under similar treatment in pots. These six trees survived the 1941 season, but all died following resumption of active growth in the spring of 1942.

The decline of the trees preceding death involved reduction in growth rate, increase in the amount of leaf burn and chlorosis, severe and progressive die-back of the smaller branches, and ultimate complete defoliation of the trees. The root systems of the high-salt trees were much less extensive than those of the controls, and roots examined prior to the death of the trees had few white root tips and exhibited a tendency to form in very fine fibrous masses.

DISCUSSION

The vegetative responses observed when peach trees are grown in sand cultures supplied with solutions containing high concentrations of chloride and sulfate salts, indicate that total concentration of salt is a major factor in the resultant general growth depression. Regardless of the salt used, the ability of the plant to grow appears to be conditioned by the total concentration of the solution. Thus, as indicated in Table II, the greatest growth depression occurred under the high sulfate treatment which had the highest osmotic concentration, 3.6 atmospheres, of the six solutions used; and the high chloride solution with an osmotic concentration of 3.4 atmospheres produced almost as severe growth inhibition. The intermediate chloride and sulfate treatments, with osmotic concentrations of 2.0 and 2.2 atmospheres respectively, induced somewhat similar vegetative responses, but, in general, there was more growth inhibition under the chloride treatment. The slightly more favorable growth obtained at the low chloride level as compared with the control trees is not conclusive, and additional data are needed to determine this point.

Although total concentration of salt appears to be the most important factor in inducing growth inhibition, it is also clear that there are specific ionic effects that must be taken into account. High concentration of the chloride ion caused marked leaf symptoms that did not occur with high sulfate concentration, and other differences in response to the two ions were observed, notably with respect to die-back. The high death rate under the high chloride treatment affords added evidence that the chloride ion is more toxic than the sulfate ion at isosmotic concentrations.

The effect of the rootstock on the vegetative response of the Elberta peach under salt treatment is apparently correlated with the relative vigor of the two root systems. At the control and low chloride levels, the trees on Shalil rootstock exhibited better growth than those on Lovell when compared with respect to secondary thickening, linear growth, weight and volume. No significant difference between rootstocks was evident under the sulfate treatments. The Lovell rootstock promoted definitely better growth than the Shalil at the intermediate chloride level; and slightly better growth at the high chloride level. A possible explanation may be advanced on the basis of the

relative vegetative vigor of the two rootstocks. The very vigorous Shalil root system is able to absorb more nutritive ions and water than the Lovell. This is advantageous at the low salt levels and results in greater growth of the scion; but may be injurious where a toxic ion, such as chloride, is present in high concentration since it results in greater intake and accumulation of the ion and consequent injury or growth depression. Chemical analyses of the leaves tend to support this theory as they show that those from the Elberta-Shalil trees accumulated more chloride than those from the Elberta-Lovell combination under the high and intermediate chloride treatments in which the former exhibit greater growth depression. This may also explain the greater salt tolerance of peaches on the less vigorous Davidiana rootstock which was observed by Chandler (1).

The possibility of progressive cumulative effects from continued salt treatment should not be overlooked in considering the growth responses of perennial plants. The behavior of the trees at the high chloride level suggests that this may be the case, and the more pronounced chloride injury to the intermediate chloride trees at the beginning of the 1942 season as compared with that of 1941 is also significant. For this reason, no final conclusions as to the maximum concentration of salts that can be tolerated or their toxic effects at a given concentration should be drawn until the trees have grown under the specified conditions for a sufficiently long time to determine whether or not maximum responses to continued treatment have been obtained.

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Self-Sterility in the Chinese Chestnut (*Castanea mollissima*)

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OBSERVERS have noted that various chestnut species usually fail to set fruit when self-pollinated. The results of breeding work at the United States Horticultural Station during the past 4 years support this observation although a few trees have produced some fruit following self-pollination. A preliminary study was made of embryo-sac development, pollen tube growth, fertilization and early embryo development in self-pollinated pistillate flowers of the chestnut to: (a) determine the stage at which the reproductive process ceases to function; and (b) explain why certain trees tend to be partially self-fruitful.

The pistillate flowers of the chestnut, usually three together, are borne in a prickly involucre on the basal portion of terminal mixed catkins. The ovary of each pistillate flower develops into the fruit or nut, and the prickly involucre becomes a spiny bur which incloses the nuts until they are mature. The ovary is 6-celled, and contains 12 to 20 ovules, the usual number being 16.

As the literature dealing with self-sterility in plants is too extensive to summarize in this paper, the references made are largely to papers dealing with *Castanea*. Stout (7) reported that chestnut trees which stand alone and isolated from other chestnut trees do not yield satisfactory crops of nuts. Regarding self-sterility, he says (p. 158): "But the self-fruitlessness of chestnuts may involve a lack of fertilization. Even when there is ample self-pollination the fertilizations necessary for the development of the seeds may not take place". Vilkomerson (9) in discussing flowering habits of the chestnut, says (p. 115): "Apparently, then, this blooming habit operates to restrict, but not wholly inhibit, close-pollination and the possibility of self-fruiting. So that the general self-fruitlessness of chestnuts is due to no lack of proper pollination, but rather to some self-incompatibility in fertilization". Benson (1) described and figured embryo sac development in *Castanea*. She placed emphasis upon certain features having phylogenetic significance in the Amentiferae, but no evidence is shown in any of her drawings that apomictic development was found. Sears (5) discusses three general types of self-sterility in flowering plants based on the degree of incompatibility of pollen and pollen tubes in tissues of the pistil, and gives an exhaustive review of the literature.

MATERIALS AND METHODS

A large seedling tree of the Chinese chestnut, *Castanea mollissima* Bl., that was known to be highly self-sterile, was used as a source of most of the material for cytological study. Two to three per cent of the self-pollinated pistillate flowers on this tree (No. 197) set fruit.

Pistillate flowers were enclosed at an early stage of development with cellophane sausage-casing bags and at the time of stigma receptivity a large number of flowers were self-pollinated, a similar number

were cross-pollinated, and a third lot received no pollen. Samples of these and open-pollinated flowers were taken weekly and fixations made during the growing season until embryo growth was observable. Langlet's modification of Navashin's fluid and formalin-acetic-alcohol were used as fixatives. The ovules were embedded in paraffin, sectioned, and stained with iron-alum-haematoxylin.

RESULTS

Data showing the set of fruit on 12 seedling chestnut trees following different methods of pollination are given in Table I. Five trees (Nos.

TABLE I—SET OF FRUIT RESULTING FROM DIFFERENT METHODS OF POLLINATING THE PISTILLATE FLOWERS OF *CASTANEA MOLLISSIMA* BL.

Tree Number	Self-Pollinated			Cross-Pollinated			Open-Pollinated			Not Pollinated		
	No. Flowers	No. Nuts Set	Percentage Set	No. Flowers	No. Nuts Set	Percentage Set	No. Flowers	No. Nuts Set	Percentage Set	No. Flowers	No. Nuts Set	Percentage Set
<i>Season of 1941</i>												
197	759	22	2.9	—	—	—	—	—	—	—	—	—
684	546	5	.9	—	—	—	—	—	—	—	—	—
767*	414	1	.2	348	90	25.9	—	—	—	—	—	—
710	66	0	.0	72	35	48.6	—	—	—	—	—	—
713	60	0	.0	69	29	42.0	—	—	—	—	—	—
448	81	1	1.2	81	63	77.7	—	—	—	—	—	—
428	90	0	.0	87	33	37.9	—	—	—	—	—	—
<i>Season of 1940</i>												
197	255	5	1.9	69	55	80.0	141	111	78.7	—	—	—
546	—	—	—	69	10	14.5	66	23	34.8	57	6	10.5
622	—	—	—	48	9	18.7	39	26	66.6	27	3	11.1
195	—	—	—	93	3	3.2	240	167	69.6	24	3	12.5
<i>Season of 1939</i>												
197	108	0	.0	—	—	—	—	—	—	—	—	—
546	108	0	.0	—	—	—	30	28	93.3	—	—	—
727	312	0	.0	—	—	—	—	—	—	132	0	.0
680	306	5	1.6	—	—	—	33	19	57.5	—	—	—
Totals	3105	39	1.3	936	327	34.9	549	374	68.1	240	12	5.0

*Hybrid (probably *Castanea sativa* Mill. × *C. dentata* Borkh.)

710, 713, 428, 546, 727) set no fruit upon selfing, while five trees (Nos. 197, 684, 767, 448, 680) were partially self-fertile. Three trees (Nos. 546, 622, 195) set some fruit without pollination. Set of fruit from open-pollinated flowers was generally higher than from those that were cross-pollinated by hand.

Each ovule may be fertilized and is capable of producing a seed, but generally only one develops to maturity in each ovary to form the one-seeded fruit or nut within a single shell. Occasionally two ovules grow to maturity in a single ovary, the two seeds being tightly pressed together within the shell of the nut, one usually larger than the other.

A study of embryo sac development in ovules of self-pollinated flowers shows that the egg apparatus develops normally in most ovules. The polar nuclei of the embryo sac fuse to form a large, deeply-staining nucleus in the center of the embryo sac. Fertilization of the egg and fused polar nuclei by male gametes from the pollen tube does not occur. Development within the ovule stops at this point, which is about 4

weeks after pollination. No endosperm is formed, although the cavity occupied by the embryo sac, called the "caecum" by Benson (1) enlarges considerably and is partially filled with prominent strands of cytoplasm. Numerous sections were found which show the presence of pollen-tube-ends within the cavity of the embryo sac, and male gametes were seen adjacent to the egg and fused polar nucleus, but syngamy was not observed. Incompatibility between male gametes and the egg apparatus is thus indicated. It has not been possible to detect the presence of pollen tubes in tissues of the stigma, style and ovary with standard methods of technique. The hard, more or less lignified nature of these tissues will undoubtedly necessitate the use of special techniques in order to follow the course of pollen tube growth.

Since tree No. 197 set a few nuts following self-pollination it was thought that a study of embryological processes might show whether these nuts developed as a result of sexual fusion or in some other manner. Several other trees (Nos. 546, 622, 195) also set a few nuts without pollination (Table I), which suggests some form of parthenogenetic or apomictic embryo development. In the sections of ovules of No. 197 numerous instances were found in which small areas of meristematic cells had developed in the center of the embryo sac. In many sections these cell masses were distinguished adjacent to the aborted fused polar nuclei, while the degenerating egg and synergids were recognizable at the micropylar end of the embryo sac. The origin of these cell groups has not been determined, neither has it been possible to determine whether or not they may continue development. Since only 2 to 3 per cent of the total self-pollinated pistils that were fixed for study showed the development of embryos, probably not enough ovules have been studied to yield the critical stages.

In a few of the ovules of No. 197 a large somatic cell of the nucellus appeared to be enlarging adjacent to the functional megaspore and pushing the latter aside, similar to the apomictic development in *Crepis* reported by Stebbins and Jenkins (6). A small number of ovules also showed partial development of an embryo, the latter with characteristic non-staining suspensor cells, but always accompanied by abortion of the polar nuclei so that no endosperm formed. Although no intermediate stages were seen, it is possible that the young embryos mentioned above develop from diploid egg cells in embryo sacs each derived from a somatic cell of the nucellus. Before the exact nature of the embryological processes involved will be understood a critical study should be made of the 2 to 3 per cent of self-pollinated pistils that set fruit.

DISCUSSION

The manner in which fruitfulness of the chestnut is affected by complex types of dichogamy and flowering habits which influence pollination has been fully discussed by Stout (8), Powell (4), and Vilkomerson (9). The fact that certain trees are slightly self-fruitful, apparently as a result of some kind of apomictic embryo development, raises other questions in regard to the general subject of fruitfulness in *Castanea*. For example, what is the frequency with which clones produce apomictic seeds under natural conditions of cross-pollination?

Trees that bear light crops of nuts under conditions favoring cross-pollination might be expected to produce a certain proportion of apomictic seeds. In this case light fruiting would presumably be due to incompatibility of available pollen, and, as is true for self-pollinated flowers described in this paper, apomictic embryo development would undoubtedly be stimulated. It should be pointed out here that Morris (3) in 1914 reported that plants of the American chinquapin (*Castanea pumila* Mill.) may set viable seeds without pollination, which indicates some kind of apomictic behavior in this species.

The frequency of apomictic seeds produced by varieties and seedling trees of *Castanea mollissima* Bl., *C. crenata* Sieb. & Zucc., and *C. sativa* Mill. has an important bearing on breeding work with these species. In making interspecific crosses the capacity of the individual tree to produce apomictic seeds would affect the proportion of hybrid nuts obtained. While the variability in most populations of seedling chestnuts indicates seed formation by means of normal reproductive processes, certain hybrid populations of young plants in the nursery are strikingly uniform in all growth characteristics. The pistillate parent trees of these uniform populations should be studied in order to determine the degree of apomictic embryo development found in the pistillate flowers.

McKay and Crane (2) reported that size of the nuts on an individual tree may be influenced by the kind of pollen used. The size of nuts containing apomictic embryos should now be determined and compared to those containing embryos resulting from fertilized eggs in order to find out what part this phenomenon plays in causing variability in size of nuts produced by a single tree.

SUMMARY

A seedling tree of the Chinese chestnut, *Castanea mollissima* Bl., is self-sterile due to incompatibility between the male gametes and the egg cell and fused polar nuclei. Pollen tubes and male gametes are found in and near the egg apparatus but fertilization was not observed to occur. Two to three per cent of self-pollinated pistils on this and certain other seedling trees of this species set fruit apparently due to apomictic embryo development.

A more critical study is necessary to determine the possible occurrence of apomixis and its nature.

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Root and Shoot Production by Young Pecan Trees Treated with Indole-Butyric Acid at the Time of Transplanting¹

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IN 1938 Romberg and Smith (1) reported that the new root growth of transplanted pecan trees was increased by treating the roots with indole-butyric acid at the time of transplanting. The effect of the hormone treatment, or of the increased root growth resulting therefrom, on the top growth of the trees had not been determined when the original announcement was made. In February 1939, a field study to determine this effect was started at the United States Horticultural Field Station, Meridian, Mississippi.

MATERIALS AND METHODS

For these experiments, 118 Schley trees having 1-year-old 6- to 7-foot tops on 3-year-old roots were used. The mean diameter of the trunks just above the base of the budded growth was 22 millimeters within a range of 18 to 28 millimeters. The standard error of the mean diameter was .19. The length of the tap roots was variable.

These trees were separated at the nursery into six groups according to the size and type of root system. Each group was then divided into two lots as nearly alike as possible, and equal in number of trees. The trees of one lot from each of the six groups were treated with indole-butyric acid. The toothpick method developed by Romberg and Smith (1) was used, four toothpicks containing 4 milligrams of indole-butyric acid each being placed in holes bored in each tree. The place of treatment, in the tap root or lateral roots, varied with the group of trees, depending on the type of root system, as follows:

Group A. Short tap root bearing only a few small laterals; all treatments made in the tap root.

Group B. Double or triple tap root; all treatments made in the tap root.

Group C. Tap root system similar to, but longer than "A"; all treatments made in the tap root.

Group D. Tap root with one to three fairly large laterals; treatments divided between the tap root and laterals.

Group E. Long tap root with several fairly large, well distributed laterals; treatments divided between the tap root and laterals.

Group F. Miscellaneous sizes and types of root systems that could not be classified with any of the above groups; treatments placed as best suited the type of root system.

¹The writer wishes to acknowledge his appreciation to Dr. C. L. Smith, co-author of the original work on the treatment of pecan roots, for his helpfulness in selecting and grouping the trees, and in treating the roots with indole-butyric acid toothpicks.

The trees used in this experiment were planted as replacements in a 30-acre block varying considerably in soil characteristics, particularly as to the proportions of sand and clay at the lower levels. One treated and one untreated tree from the same root-type group were planted as near each other as possible, and the pairs from all groups distributed at random throughout the orchard. The holes for planting were dug with shovels, and as the soil was quite moist, no water was added. The earth was tamped firmly into the holes with sticks, care being taken to keep the small roots spread out away from the tap roots. The tops of the trees were cut back to approximately 2 feet above the ground. No fertilizer was applied at planting time, but two applications of about $\frac{1}{2}$ pound of nitrate of soda per tree were made in late May and early July each year. A pound and a half of 6-8-4 commercial fertilizer per tree was applied in April 1940, and the same amount of 4-8-4 fertilizer in 1941. The trees received no water other than rain. Weed and grass growth was kept down by mowing in 1939, by mowing and one tree-row cultivation in 1940, and by clean cultivation in 1941. Grass and weeds were kept hoed away from immediately around the tree trunks.

ROOT PRODUCTION

After the trees had grown one year in the orchard, one treated and one untreated tree in each group, as nearly alike as could be determined from the tops, were dug and photographed, the new roots removed and weighed, and the trees again photographed. Data for fresh weights of the new roots produced are presented in Table I.

TABLE I—NEW ROOT PRODUCTION BY SCHLEY PECAN TREES TREATED OR NOT TREATED WITH INDOLE-BUTYRIC ACID AT THE TIME OF TRANSPLANTING

Group	Fresh Weight of New Roots on Treated Tree (Gms)	Fresh Weight of New Roots on Untreated Tree (Gms)	Difference in Favor of Treated Trees (Gms)
A	18.5	0.3	18.2
B	119.0	41.0	78.0
C	37.5	21.0	16.5
D	177.5	55.5	122.0
E	101.0	25.0	76.0
F	92.0	17.5	74.5
All.....	545.5	160.3	385.2
Mean.....	90.9	26.7	64.2*
Standard error of the difference.....			24.7

*The difference is significant.

As the pairing of tops was found not to be a reliable method of pairing root systems, the significance of the difference in the weights of new roots produced by the treated and untreated trees was determined for group comparisons using Snedecor's method (2). The difference was found to be significant. The results indicate that a definite increase in root production was brought about by the indole-butyric acid treatment, thereby substantiating the original work of Romberg and Smith. The increased root production on the treated trees as compared with untreated ones is clearly shown in Figs. 1 and 2.



FIG. 1. Pecan trees from group C, each originally with long tap root and a few small laterals. Treatments only in the tap root. A, showing new roots produced in 1939 on a treated (left) and an untreated (right) tree. B, same trees after removal of new roots.



FIG. 2. Pecan trees from group E, each originally with long tap root and several fairly large, well distributed laterals. Treatment divided between the tap root and laterals. A, showing new roots produced in 1939 on a treated (left) and an untreated (right) tree. B, same trees after removal of new roots.

STAND OF TREES

Counts made on September 9 and 10, 1940, after two growing seasons in the orchard, showed that the treatments had no effect on the percentage of transplanted trees that lived or died.

SHOOT PRODUCTION

The new shoot growth for each season was measured in late summer or fall for three successive years following transplanting. Only the living trees that had not been disturbed for examination of the root systems or other purposes, were measured. The data are presented in Table II, and have been analyzed by Snedecor's method (2) of making group comparisons. The treated trees made more growth during the second and third seasons but the differences were not statistically significant.

The absence of any increase in top growth of the treated trees over the untreated ones in the season immediately following transplanting is not wholly unexpected. It would be a logical supposition that, during the year in which additional new roots are being formed as a result of the hormone treatment, food reserves are utilized for root production to an unusually large extent, and that top growth would be no greater, and might even be less, than on similar untreated trees. The corollary to this supposition is that the top growth of the treated trees would be greater in succeeding years than that of the untreated trees, due to the increased number of roots produced the first year by the hormone treatments, this larger root system being capable of absorbing additional water and mineral solutes, especially nitrogen, that would stimulate top growth of the treated trees. The data (Table II) show that

TABLE II—TERMINAL SHOOT GROWTH MADE BY SCHLEY PECAN TREES TREATED OR NOT TREATED WITH INDOLE-BUTYRIC ACID AT THE TIME OF TRANSPLANTING

Group	Treated Trees		Untreated Trees		Mean Gain of Treated Over Non-Treated Trees (Cms)	Standard Error of the Difference (Cms)
	Number	Mean Total Length of New Shoots Per Tree (Cms)	Number	Mean Total Length of New Shoots Per Tree (Cms)		
1939						
A	10	61.38	10	47.71	13.67	14.51
B	6	108.68	6	81.87	26.81	107.81
C	8	77.71	8	85.21	-7.50	20.38
D	13	79.62	13	58.57	21.05	19.57
E	6	78.35	6	102.93	-24.48	78.25
F	16	63.21	16	84.84	-21.32	13.14
All....	59	74.66	59	74.34	0.32	7.99
1940						
A	8	42.94	7	55.50	-12.56	14.89
B	5	238.30	5	125.60	112.70	138.45
C	5	156.40	5	107.00	49.40	61.58
D	12	77.13	11	78.27	-1.14	29.25
E	4	97.50	4	198.38	-100.88	78.92
F	13	135.42	15	109.37	26.06	49.00
All....	47	114.74	47	103.12	11.62	21.81
1941						
All....	26	250.19	34	194.03	56.16	67.84

there was a tendency in that direction since the treated trees made slightly more growth than the untreated trees during the second and third growing seasons.

EFFECT OF ORIGINAL ROOT SYSTEM ON TOP GROWTH

The differences between the mean shoot growth produced by the trees in the five distinct root type groups were determined. The miscellaneous group, F, was omitted. As no statistically significant difference was found between the shoot growth of the treated and untreated trees, all trees in each group were included in the calculations on root type influence. The data are given in Table III. The trees in group B,

TABLE III—DIFFERENCES IN TERMINAL SHOOT GROWTH MADE BY YOUNG SCHLEY PECAN TREES HAVING DIFFERENT TYPES OF ROOT SYSTEMS

Group	Mean Shoot Growth (Cms)	Gain of "B" Over Other Groups		Gain of "E" Over Groups "C", "D" and "A"		Gain of "C" Over Groups "D" and "A"		Gain of "D" Over Group "A"	
		Mean Difference	Standard Error of Difference	Mean Difference	Standard Error of Difference	Mean Difference	Standard Error of Difference	Mean Difference	Standard Error of Difference
1939									
B	95.3	—	—	—	—	—	—	—	—
E	90.7	4.6	28.2	—	—	—	—	—	—
C	81.5	13.8	26.2	9.2	17.5	—	—	—	—
D	69.1	26.2	26.3	21.6	17.6	12.4	14.2	—	—
A	54.5	40.8	25.3	36.2*	16.1	27.0*	12.3	14.6	12.4
1940									
B	182.0	—	—	—	—	—	—	—	—
E	147.9	34.1	72.0	—	—	—	—	—	—
C	131.7	50.3	66.4	15.2	51.1	—	—	—	—
D	77.7	104.3	63.2	70.2	43.5	54.0	26.7	—	—
A	48.8	133.2*	59.3	99.1*	44.9	82.9*	30.5	28.8	14.7
1941									
B	309.1	—	—	—	—	—	—	—	—
E	208.3	100.8	102.2	—	—	—	—	—	—
C	273.6	35.5	98.7	-65.3	105.7	—	—	—	—
D	91.9	218.0*	67.7	117.2	78.2	182.5*	72.8	—	—
A	122.3	186.8*	68.3	86.0	78.7	151.3	73.4	-31.2	18.0

*Differences are significant.

with double or triple tap roots, had the largest root systems of those in any of the groups, and produced the greatest mean top growth in 1939, 1940 and 1941. The group E trees, with the next to largest root systems, long tap roots and several fairly large well distributed laterals, produced the next greatest top growth in all three years. The group A trees, those with the smallest tap roots and no laterals, made the least growth in 1939 and 1940 and the next to least in 1941. Because of the wide variation between growth of individual trees, the differences between the group means are not significant in all cases when analyzed by Snedecor's method (2) for making group comparisons. However, enough of the differences are statistically significant to indicate that, in general, better growth may be expected on trees with large and well branched root systems at time of transplanting than on trees with small tap roots and no laterals.

Considering the results obtained in these studies, an experiment has been started in which the roots of a number of nursery seedlings were treated with indole-butyric acid in the year in which the buds were set to determine if the root systems can be sufficiently increased in the nursery so that the trees will make better growth after being transplanted.

SUMMARY

An experiment was conducted to study the root and shoot growth of young pecan trees treated or not treated with indole-butyric acid at the time of transplanting. One hundred eighteen Schley trees were used, 59 treated with impregnated toothpicks and 59 left untreated. The new root growth of the treated trees was found to be significantly greater than that of the untreated trees. No significant differences were found in the shoot growth of the treated as compared with the untreated trees, although there was a tendency in favor of the treatments. Trees with large and well branched root systems at time of transplanting were found, in general, to make better top growth than trees with small tap roots and few or no laterals.

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Fertilization of Tung Seedlings in the Nursery

By SAMUEL MERRILL, JR. and W. WILSON KILBY, *U. S. Department of Agriculture, Bogalusa, La.*, and S. R. GREER, *Mississippi Experimental Tung Field Station, Poplarville, Miss.*

TUNG seeds planted in the nursery germinate rather slowly and, after the seedlings emerge from the soil, they go through an apparent rest period of 4 or 5 weeks before commencing active growth. Even though the seeds are planted late in February or early in March, the plants make little growth before the first of June. However, there is no difficulty in producing trees large enough to transplant to the orchard by the end of the first season, and widespread interest is now being shown in budded tung trees for commercial planting. Experiments to date indicate that the most advantageous budding season is late August and September. To get the nursery seedlings large enough to bud in August is a problem. The fertilization of the trees in the nursery is a part of this general problem, which is under study at the laboratories of the Division of Fruit and Vegetable Crops and Diseases of the Bureau of Plant Industry. The work reported here was done in cooperation with the Mississippi Experimental Tung Field Station.

The standard practice in fertilization of tung nurseries has been to side dress the seedlings with 200 to 300 pounds of 4-8-4 fertilizer just after they emerge from the soil. However, in one or two instances growers seemed to get exceptionally good results from the use of about 200 pounds per acre of a 4-8-4 fertilizer in the row at planting time. The fertilizer was distributed by hand in a furrow, a log chain was dragged over it to incorporate it in the soil and the seeds were then immediately planted. Growers have also reported good results from the use of pulverized press cake from the tung mills (tung meal) in the row at planting time. It seemed possible or even likely that nutrients available to the roots of the seedling soon after germination, might tend to make it start growth and thus overcome the apparent rest period previously mentioned.

MATERIALS AND METHODS

Accordingly in the spring of 1941 an experiment was set up at the Mississippi Experimental Tung Field Station in Pearl River County, Mississippi, to test three factors; (a) commercial fertilizer in the row before planting; (b) tung versus cottonseed meal in the row before planting; and (c) commercial fertilizer as a side dressing. The soil has been classified as Bowie, which is somewhat similar to a Norfolk fine sandy loam, but definitely inferior. It is fairly well drained but rather infertile.

The first factor, 8-8-6 mixed fertilizer in the row at planting time, was used at three levels; namely, 0, 200 and 400 pounds per acre. The second factor, 8-8-6 mixed fertilizer as a side dressing, was used at two levels; namely, 0 and 200 pounds per acre. The third factor consisted of three levels of organic nitrogenous meals in the row at planting time; namely, no meal, 650 pounds of tung meal per acre, and 650 pounds of cottonseed meal per acre. The pulverized tung cake

used in this experiment came from a lot that contained 3.4 per cent N, 1.2 per cent P_2O_5 and 1.3 per cent K_2O . The cottonseed meal used was not analyzed, but was assumed to be of average composition, about 7 per cent N, 2.5 per cent P_2O_5 and 2.0 per cent K_2O . All combinations of the different levels of these three factors were used, giving a total of 18 treatments arranged in factorial design. This design is especially advantageous in that both the main effects of the three factors and their interactions can be accurately determined. Four replications of the 18 treatments were used, making a total of 72 plots. Because all soils in the Coastal Plains area are exceedingly variable, the 18 treatments of each replication were broken down into three blocks of six each for better error control. This was accomplished by partially confounding the degrees of freedom for two of the least important interactions. This design permits the recovery of a portion of the information on the interactions thus confounded and results in more accurate measurement of the main effects and remaining interactions.

The seed were planted on March 13 in "beds" 4 feet apart. The open pollinated seed from a single tree, RS-139, was used for the planting of the plots and the guard rows between plots and around the borders of the experimental area. A deep furrow was made in the bed with the implement known in the South as a "bull tongue". Since the plots were small, the bottom of the furrow was then leveled off with a hand hoe and the fertilizer or meal applied by hand in a wide band. A layer of soil about $1\frac{1}{2}$ inches deep was then raked over the fertilizer, the seed planted 12 inches apart in the row, and covered to a depth of 2 inches. The side dressing was applied June 3, in a shallow furrow on one side of the row and about 8 inches from the seedlings. Twenty seeds were planted in each plot but due to a very severe drought, the germination was poor. On June 17, when the seedling trees were just commencing to produce true leaves, trees were transplanted from the guard rows to certain plots to give a uniform number of 12 trees per plot.

Although a severe drought occurred early in the season, after June 10 conditions were favorable for growth and the trees attained reasonably good size. Measurements of the height to the terminal bud and of the diameter at 15 centimeters above the ground, were made on October 23. Scarcely any of the trees branched, and therefore no records of number or length of branches were taken.

RESULTS

An analysis of variance for the data on height and diameter is given in Table I and the average height in centimeters of the trees under each treatment is shown in Table II. It is to be noted in Table I that the trees in the various treatments differed significantly in height but not in diameter. For this reason further data on diameter are not presented here.

The main effect of 8-8-6 fertilizer as a side dressing has statistical significance just above the .05 level but the significance of its effect as a row application is considerably lower. Yet the interaction between these two factors is very highly significant, the value of *F* being 7.15

TABLE I—ANALYSIS OF VARIANCE FOR FERTILIZER TREATMENTS IN THE TUNG NURSERY

Source	D.F.	Height		Diameter		P. Re- quired at .05 Level
		Variance	F. Found	Variance	F. Found	
Blocks	11	606.53	2.92*	.0723	1.67	2.02
Levels of 8-8-6 in row	2	549.40	2.64	.0674	1.56	3.22
Meals	2	121.21	—	.0860	1.99	3.22
Levels of 8-8-6 side dressed ..	1	864.59	4.16	.0416	—	4.07
Interaction levels of 8-8-6 in row X meal†	4	290.33	1.40	.0366	—	2.59
Interaction levels of 8-8-6 in row X level of 8-8-6 side dressed	2	1487.24	7.15*	.0986	2.28	3.22
Interaction meals X level 8-8-6 side dressed	2	210.60	1.01	.0142	—	3.22
Interaction meals X level 8-8-6 in row X level	4	257.03	1.24	.0270	—	2.59
Remainder (error)	43	207.92	—	.0432	—	—
Total	71	—	—	—	—	—

*Significant at .01 level.

†Partially confounded—information equivalent to seven-eighths of the plots.

‡Partially confounded—information equivalent to five-eighths of the plots.

where 5.15 is required at the .01 point. Referring to Table II, the reasons become clear. In those plots where no side dressing was used, 8-8-6 fertilizer in the row produced a highly significant increase in the size of the trees. *In those plots that were side dressed, the effect of 8-8-6 fertilizer in the row is negligible.* Since half of the plots were side dressed, the effect of 8-8-6 in the row taken over the whole experiment is hardly significant. Similarly, when no 8-8-6 fertilizer had been used

TABLE II—HEIGHT OF TUNG TREES HAVING DIFFERENT FERTILIZER TREATMENTS IN THE NURSERY

Meal	Not Side Dressed Level of 8-8-6 in the Row			Side Dressed With 200 Pounds 8-8-6 Per Acre Level of 8-8-6 in the Row			Average 24 Plots (Cm)
	None (Cm)	200 Pounds Per Acre (Cm)	400 Pounds Per Acre (Cm)	None (Cm)	200 Pounds Per Acre (Cm)	400 Pounds Per Acre (Cm)	
None	49.9	83.8	93.8	91.0	92.0	85.0	82.6
Tung	62.2	84.4	80.9	85.1	88.0	70.2	78.5
Cottonseed ..	75.8	84.7	73.6	86.3	74.8	79.0	79.0
Average 12 plots	62.6	84.3	82.8	87.5	84.9	78.1	80.0
Average 36 plots	Not Side Dressed 76.6			Side Dressed 83.5			
Average 24 plots	No 8-8-6 in row, 75.0		200 pounds per acre 8-8-6, 84.6	400 pounds per acre 8-8-6, 80.4			

Error of Difference Between Means

Number of Plots Averaged

	4	12	24	36
Standard error of difference of two means	10.2	5.9	4.2	3.4
Least difference significant at .05	20.6	11.9	8.5	6.9
Least difference significant at .01	27.6	16.0	11.4	9.2

NOTE: The height for each of the 18 treatments is the average for four plots of 12 trees each.

in the row, side dressing produced a very large increase in growth, but there was little or no gain, from the use of side dressing on trees already fertilized with 8-8-6 mixed fertilizer in the row. Either treatment alone gave substantially as good results as the two together. Thus the interaction between the two is the most significant fact brought out in this investigation. Although the trees side dressed with 200 pounds per acre of 8-8-6 were slightly larger than those having the same fertilizer in the row, 87.5 centimeters versus 84.3 centimeters, the difference is of no significance. The accuracy of this experiment is such that no conclusion is justified as to which of these two methods of application is the better.

It is to be noted that among the plots not side dressed, the average height of the trees that received 200 pounds per acre of 8-8-6 fertilizer in the row was 84.3 centimeters, and that the height of those trees that received 400 pounds per acre of 8-8-6 in the row was 82.8 centimeters. Since the seed was directly above and rather close to the band of fertilizer, the failure to respond to the larger amount might be due to injury from concentration of salts. However, the result from 400 pounds of 8-8-6 in the row differs but little from that resulting from the same quantity of fertilizer, half applied in the row and half as a side dressing. In fact, considering all the treatments, growth was not improved by using more than 200 pounds per acre of 8-8-6 fertilizer, either under the row or as a side dressing.

Over the whole experiment the two kinds of organic meals produced no effect. In 60 out of the 72 plots, the meal was used as a supplement to an application of at least 200 pounds per acre of 8-8-6 fertilizer. In the 12 plots that received no 8-8-6 fertilizer, there is some evidence that cottonseed meal improved the growth. This is of more experimental than of practical significance. Because of the greater cost for quantities used, the cottonseed meal could not be substituted for the 8-8-6 mixed fertilizer, and it was of no value as a supplement. The results of this experiment make the value of tung meal rather problematical. Although its cost is likely to be low, better results than those obtained in this experiment would be needed to justify its use.

SUMMARY AND CONCLUSIONS

Under the conditions of this test, 200 pounds per acre of an 8-8-6 mixed fertilizer applied either in the row at planting or as a side dressing gave as good results in the tung nursery as heavier applications. When used alone at the rate of 650 pounds per acre, tung meal and cottonseed meal gave results inferior to the 8-8-6 fertilizer, and when used as a supplement to 200 pounds per acre of the 8-8-6, no effect whatsoever was observed.

Choice of Parent as Influencing Seed Germination in Fruits

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FRUIT breeders are often beset with the difficulty of obtaining good germination of hybrid seed, even though the parents may be compatible varieties of the same species, and differences in chromosome number do not exist. Very few breeders have paid attention as to whether one variety or the other is used as the female in making cross pollinations, as long as the fruit set is sufficient.

Germination of the seed depends primarily on (a) the inherent soundness of the seed itself, that is, whether all of the necessary tissues and organs are so formed and matured that germination can proceed if the proper conditions are supplied, and (b) the subsequent treatment of the seed, that is, the supply of the necessary chilling requirement, temperature, moisture, and aeration to create those physiological responses necessary for growth. The factors of the second category are now fairly well-defined, and in general present no great obstacles. But it appears that many of the failures to obtain good germination are those found in the first category, and have to do with factors more difficult or at present beyond our control. Considerable progress has been made in obtaining germination of seeds once considered inviable by use of the embryo culture technique (1, 7, 10), but with some fruit varieties this is at present inapplicable. The seeds of many early ripening varieties of peaches cannot be cultured successfully (6). In other fruits, such as the grape, where the embryo is very small and encased in very hard seed coats, even dissecting out the embryo is impractical.

The purpose of this paper is to present some data and observations that indicate that poor seed germination in cultivated fruit varieties may often be circumvented by the proper choice of the maternal parent. The conception put forward is that the formation of viable seed is largely independent of the genetic constitution of the young hybrid embryo or endosperm. In some case the embryo sac, seed coats, or nucellus may develop so abnormally that fertilization is precluded, and we fail to obtain hybrid zygotes. Cases of this type are well recognized. But for many fruits fertilization proceeds in pace, and even the seed at maturity may appear quite normal externally. This seed may show very low germination, and it matters very little as to what variety is used as the pollen parent. Thus the production of seed of low viability is largely determined by the maternal genotype, affected in some way by the abnormal relationship of the tissue systems in which the embryo and endosperm develop or with which they come in contact, and dependent in turn on how they fail to develop properly after fertilization.

In the grape many varieties are characterized by having seeds in which the integuments fail to develop normally and there is a cessation of endosperm development. The seeds of such varieties are hollow at maturity and seldom germinate, even though many appear normal externally and reach full size. In a previous paper (8) it has been pointed out that it is characteristic of many varieties to repeatedly

produce a large percentage of such defective seeds year after year. If two varieties are interbred, the percentage of viable seed obtained may be vastly different, depending on the variety chosen to be the maternal parent (Table I). Pearl of Csaba, when self-pollinated or

TABLE I—GERMINATION OF GRAPE SEED FROM SOME SELF-POLLINATIONS, CROSSES, AND THEIR RECIPROALS

Cross	Year	Female Parent	Male Parent	Number Seeds Harvested	Per Cent Germination
1	1935	Pearl of Csaba	Self-pollinated	513	2
2	1935	Pearl of Csaba	Portuguese blue	206	1
3	1935	Portuguese blue	Pearl of Csaba	115	48
4	1938	Pearl of Csaba	Concord	116	0
5	1938	Concord	Pearl of Csaba	90	31
6	1938	Pearl of Csaba	Golden Muscat	163	1
7	1938	Golden Muscat	Pearl of Csaba	200	32
8	1938	Golden Muscat	Self-pollinated	100	20
9	1937	Pearl of Csaba	Champion	172	0
10	1937	Champion	Pearl of Csaba	107	80
<i>Cornichon as Female Parent</i>					
11	1939	Cornichon	Self-pollinated	200	72
12	1939	Cornichon	Folle blanche	161	86
13	1939	Cornichon	Muscat of Alexandria	182	79
14	1939	Cornichon	Zinfandel	274	74
15	1940	Cornichon	Zinfandel	69	80
<i>Folle Blanche as Female Parent</i>					
16	1930	Folle blanche	Self-pollinated	400	28
17	1942	Folle blanche	Self-pollinated	400	31
18	1939	Folle blanche	Cornichon	57	58
19	1930	Folle blanche	Muscat of Alexandria	109	59
20	1939	Folle blanche	Zinfandel	203	55
<i>Muscat of Alexandria as Female Parent</i>					
21	1941	Muscat of Alexandria	Self-pollinated	200	79
22	1932*	Muscat of Alexandria	Open-pollinated	300	84
23	1941	Muscat of Alexandria	Cornichon	38	76
24	1941	Muscat of Alexandria	Flame Tokay	84	74
25	1941	Muscat of Alexandria	Folle blanche	141	91
26	1941	Muscat of Alexandria	Zinfandel	192	93
27	1932	Muscat of Alexandria	Sultanina	200	75
28	1939	Muscat of Alexandria	Sultanina	86	75
29	1932	Muscat of Alexandria	Black Corinth	100	94
30	1931	Muscat of Alexandria	Monukka	43	82
<i>Zinfandel as Female Parent</i>					
31	1941	Zinfandel	Self-pollinated	200	34
32	1941	Zinfandel	Cornichon	309	34
33	1941	Zinfandel	Folle blanche	151	66
34	1941	Zinfandel	Muscat of Alexandria	198	63
35	1937	Zinfandel	Refosco	175	57
36	1937	Zinfandel	Teoulier	103	67
37	1937	Zinfandel	Sultanina	240	50

*Data from (8).

cross-pollinated with other varieties, yields less than 2 per cent of viable seed when used as maternal parent. But if pollen from the Pearl of Csaba is used on another variety of high germination capacity, for example Champion, many hybrid seedlings may be obtained. This is not an isolated example, since the same phenomenon may be demonstrated to exist in varieties that show fair to good viability of the seed. Thus in Table I the Cornichon and Muscat of Alexandria both produce seed that is considered to give very good germination, and this is almost wholly independent of the pollen parent used. Folle blanche and Zinfandel seeds germinate fairly well, but the percentage of viable

seed is much below that of the Muscat or Cornichon. If Muscat of Alexandria is to be hybridized with the Folle blanche, however, or the Cornichon with the Zinfandel, one can readily see that the best seed germination is obtained by using the variety with the highest seed viability as the female parent. Compare crosses 12 with 18, and 14 with 32. Data concerning the seed viability of grape varieties is now used in planning crosses between them, and the variety with the better germination is selected as the maternal parent. This has enabled us often to obtain a large percentage of hybrid seedlings, whereas formerly we had to be content with many failures in germination.

In the peach the same situation appears to be true, as germination of many varieties, particularly the early ripening ones, is poor, (4). The variety Lukens Honey produces seed that is highly viable (Table II). Again this high seed viability is determined by the maternal

TABLE II—SEED GERMINATION IN SOME RECIPROCAL CROSSES OF PEACH VARIETIES*

Cross No.	Year	Female Parent	Male Parent	No. Seeds	No. Germinated	Per Cent Germinated
1	1939	Lukens Honey	(selfed)	226	194	86
2	1939	Lukens Honey	Open-pollinated	350	308	88
3	1940	Lukens Honey	Early Imperial	52	47	90
4	1940	Lukens Honey	Mayflower	26	20	77
5	1940	Early Imperial	Lukens Honey	12	6	50
6	1940	Mayflower	Lukens Honey	32	0	0
7	1938	Late Elberta	Mayflower	68	20	29
8	1938	Mayflower	Late Elberta	24	0	0
9	1939	Shalil	Late Elberta	106	89	84
10	1939	Late Elberta	Shalil	72	18	25

*Pits were placed in mixture of moist, clean sand and peat moss held at 32 degrees F for 2 months. The kernels were then split out and germinated in sterilized sand culture, without disinfection.

parent, the pollen parent appears to influence the results but little, if any. When the early ripening varieties such as Mayflower and Early Imperial are used as pollen parents, the germinability of the seed does not appear to be much influenced. However, if the cross is made in the reciprocal, Mayflower ♀ × Luken's Honey ♂, no viable seed has been obtained. If the hybridizer wished to make this cross, obviously the Luken's Honey should be chosen as the female parent. The data for the variety Late Elberta shows this same tendency, which indicates that this phenomenon of maternal control does not only apply to cases where the viability is very low, but to intermediate degrees of inviable seed formation as well.

Lammerts (7) used the Mayflower as female parent in crossing with the July Elberta. Out of a total of 150 pits, 112 had aborted embryos which were incapable of germination. In using the Early Imperial as female he obtained aborted embryos in rather low numbers, 11 out of 81 pits when Vainqueur was used as pollen parent, and 7 out of 102 pits when July Elberta was used as pollen parent. The pollen parent did not greatly influence the number of abortive embryos obtained.

Data for reciprocal crosses of cherry varieties having different seed viabilities are not yet available, but the fact that many early ripening varieties have been used as female parents in cross pollinations with other varieties without obtaining good germination would support the evidence given for the grape and peach. It is to be hoped that this study may be extended to other fruits, to determine if the findings have general application.

DISCUSSION

Especially in the grape, and perhaps for many other deciduous fruits as well, the failure to form structurally normal and mature seed is already determined by the maternal genotype long before the time of fertilization. Thus the particular genetic constitution of the developing embryo or endosperm are not the important factors determining the formation of inviable seed. Brink and Cooper (2) have used the term "somatoplastic sterility" to describe the phenomenon in which ovules collapse in development during the early post-fertilization stages, since the essential feature leading to the collapse was stated to be the excessive growth of the maternal tissues bordering the embryo sac, with subsequent starvation of the endosperm. They place particular emphasis upon the genetic constitution of the developing endosperm, since in hybrid seed its growth is more rapid than in seed resulting from self-pollination (5). Unquestionably the hybrid constitution of endosperm and embryo results in a greater growth rate from fertilization onwards and this would be only the manifestation of "hybrid vigor" as seen in the earliest stages of zygotic development. Thus it has been our experience that in the grape the germination of hybrid seed — even between varieties of the same species, practically always exceeds that of self-pollinated seed. The data given on grape seed germination in Table I indicates this as well. In a recent paper, Brink and Cooper (3) have reviewed some cases of seed abortion in the drupaceous fruits and also in grapes, emphasizing the importance of recognizing that the course of development leading to abortive or defective seeds in the drupes has its inception in an unbalance in early growth between the endosperm and adjacent maternal tissues, and so the causes of such abortions must be looked for in the early post-fertilization stages. However, despite the fact that our data is limited to the grape and the peach, it is apparent that the development or disposition of the maternal tissues themselves is the more important factor and the later abortive condition of the endosperm or embryo follows because of such an unbalance. This seems to be the only reasonable explanation of the vast differences present in reciprocal crosses of heterozygous fruits, in which the genetic constitution of both endosperm and embryo are subject to wide variation, and hence differences in growth rate and development.

However, the fact that self-fertilized seeds are less viable than cross-fertilized ones, would indicate that the hybridity of endosperm or embryo is also a factor of some importance. But in examples where the seed viability is very low, it is apparent that this condition is controlled to a much greater degree by the maternal tissues than by

the zygotic tissues. The abnormal growth or nutritional relationships associated with seed abortion are unquestionably genetic in nature, and it would appear that they are determined in rather simple fashion. For example, the inheritance of seedlessness in the Sultanina grape appears to be dependent on a single dominant factor (9). However, another type of seedlessness in the grape in which the embryo sac is usually so malformed that fertilization is impossible is recessive in nature (9). It would therefore be premature to generalize upon the causes of seed abortion in fruits, as unquestionably there are many different manifestations and causes of this abnormal behavior, just as their genetic control by the maternal genotype appears to have arisen by quite independent mutations.

SUMMARY

It is shown in the grape and peach that the production of seed of low viability is largely determined by the maternal genotype. This same phenomenon might also apply in other fruit plants.

The fruit breeder should therefore, when possible, select as the female parent the variety known to have the highest seed viability.

It appears that seed abortion may be manifested in several ways and have diverse causes, as its genetic basis, at least in the grape, may be traced to independent gene mutations, each of which produces a different type of seed abortion.

Seed abortion in some fruit varieties, since it is largely determined by the genotype of the maternal tissue and not so much by the hybridity of the developing zygotic tissues, must certainly be attributed to the abnormal growth or nutrition of the maternal tissues, the abortion of embryo or endosperm being a secondary reaction.

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Pollination Studies with Tung Trees

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SINCE the growing of tung (*Alcurites fordii* Hemsl.) in the United States has become an important horticultural industry, considerable effort is being expended toward developing varieties through selecting and breeding. There seems to be no difficulty in obtaining a satisfactory set of fruit under orchard conditions, but in connection with breeding problems it is important to know more about how pollination and fertilization in tung takes place. The methods used and care needed in making controlled crosses depend to a great extent upon how the pollen is distributed to the stigmas. In order to obtain information on this problem, an extensive experiment was set up in the spring of 1940, but a late spring frost killed nearly all of the flowers on the experimental trees. The experiment was repeated in the spring of 1941.

During the first season of breeding work at the United States Department of Agriculture Tung Laboratories, pollen was collected in small glass vials. It was planned to transfer the pollen from the vials to the stigmas with a small brush, but it was found to be so sticky that it could not be handled in this manner. Nevertheless the pollen sheds rather freely about one day after anthesis. When shaken onto glass slides and examined under the microscope it is found largely in groups, though there are numerous single grains. The individual grains are large, averaging about 65 microns in diameter. Small grains about 35 microns in diameter occur occasionally.

To determine how generally and how far tung pollen is carried by the wind, 3-inch by 1-inch microscope slides with one surface evenly covered with white petroleum jelly were exposed in two different orchards. These slides were placed at distances ranging from 15 to 100 feet and in various directions from the nearest tung tree. They were left in place 2 days at the peak of the blossoming period. During this time there was an almost constant wind. From 1 to 90 grains of tung pollen were found on each of the slides exposed within 15 to 40 feet from the trees. Frequently the grains were in groups. For instance, one slide with a total of 70 grains had two groups of 6, one group of 8, one of 20, and one of 30. Only two grains of pollen were found on four slides exposed at distances ranging from 60 to 100 feet from the trees. Under orchard conditions practically every ovule of every pistillate flower develops a seed. Hence at least one pollen grain must lodge on each of the four or more stigmas of each flower. Although the series of observations described indicates that tung pollen may be carried by the wind as far as 100 feet, it is quite unlikely that wind alone could effect the almost perfect pollination known to take place in the orchard.

Honey bees have been found working on tung flowers and since they have been shown to be an important agency in the pollination of several

kinds of fruits, their role in the pollination of tung flowers was studied. A tree was enclosed by a frame of two by four timbers over which a light muslin cloth was stretched. A hive containing a small colony of bees was placed in this enclosure and remained there until the blossoming period had passed. Another tree was likewise covered but no bees were placed in the enclosure. About one half the area of a third small tree was enclosed with a muslin cover and the other half left exposed. The number of flowers used in each case was not counted. The set of fruit on the tree with the bees was very good. On the tree enclosed but from which bees were excluded, a number of controlled pollinations were made; and both crossed and selfed flowers set fruit nearly 100 per cent. During the period when pollen was shedding freely on this tree, the branches were shaken vigorously in order to distribute the pollen as much as possible; yet not a fruit set from the flowers that were not pollinated by hand. On the tree where half the area was enclosed, 23 fruits set while on the exposed half, 58 fruits set. On these trees no count of the seeds in each fruit was made. It might be thought that the increased set was due to crossing as compared with selfing, but in selfing and crossing a considerable number of tung trees scattered throughout the tung belt of the United States, no case of self-sterility has been found. The decreased set inside the tent was no doubt due to absence of flying insects, such as honey bees.

A number of more precise experiments were set up to gain further evidence on how pollination is effected in the orchard. In each case the conventional data on percentage of flowers to set fruit and number of seeds per fruit were taken. However, data on the percentage of tung flowers setting fruit do not have their usual significance because the fruits hold very tenaciously and will rarely drop even if only one ovule is fertilized. The fruits of the trees used in these experiments have five carpels each, or rarely four, and there is one ovule in each carpel.

This fact makes it possible to use the number of seeds or nuts developed per flower pollinated as a criterion of the efficiency of pollination and fertilization. It has been found that this criterion is less subject to fluctuation and more accurate than either percentage of flowers to set fruit or number of nuts per fruit set (1). In this paper results will be expressed both on the basis of percentage of flowers to set fruit and number of nuts per flower pollinated. Number of nuts per flower pollinated is equivalent to expressing results on the basis of the percentage of the *ovules* to develop seed. Data on number of nuts per fruit will be omitted, because statistical analysis indicates that these have no significance.

As a test of the efficiency of the kraft paper bag in preventing pollination, 167 pistillate flowers on six trees were enclosed prior to anthesis, the staminate flowers being removed from each cluster at the time of bagging. The bags were held closed about the branches supporting the flowers by tying tightly with heavy twine. Not a single fruit set from the 167 flowers. No large insects could have reached the flowers in these bags. It may be concluded that if any small insects entered, they carried no pollen.

One hundred and sixty-two pistillate flowers on six trees, together with the staminate flowers in the same clusters, were enclosed in kraft paper bags just prior to anthesis. Of these flowers, 4 per cent set and produced fruit, and there was an average of $0.15 \pm .12$ nuts per pistillate flower exposed. As suggested above, small insects may have gained entrance to these bags, and if so could have transferred pollen from the staminate to the pistillate blossoms within. However, it seems probable that this pollination was effected mechanically. Free movement of the flowers within the bag was largely prevented since they were crowded, but limited mechanical pollination probably occurred.

In order to expose stigmas to pollen carried by the wind or falling from flowers above and yet prevent pollination by large insects, the following experiment was made. Just prior to anthesis, 86 pistillate flowers on seven trees were enclosed by means of envelopes constructed of 16-mesh wire screen. All staminate flowers were removed from the screen enclosure. Fifty-two per cent of the flowers set and produced

TABLE I—SET OF FRUIT AND AVERAGE NUMBER OF NUTS PER FRUIT RESULTING FROM PISTILLATE FLOWERS EXPOSED TO DIFFERENT CONDITIONS FOR POLLINATION

Treatments Flowers	Number of Trees	Total Number Pistillate Flowers	Fruits Set (Per Cent)	Nuts per Pistillate Flower	
				Average Number	Variance
Staminate removed; pistillate bagged before anthesis.....	6	167	0	0.00	.000
Staminate and pistillate bagged together before anthesis.....	6	162	4	$0.15 \pm .12$	.0137
Staminate removed; pistillate covered with 16-mesh screen.....	7	86	52	$1.39 \pm .24$	.0600
Staminate and pistillate covered together with 16-mesh screen.....	6	70	36	$1.10 \pm .26$	.0700
Corollas removed from pistillate prior to anthesis; staminate removed; covered with screen.....	4	40	43	$0.85 \pm .32$	.1050
Corollas removed from pistillate prior to anthesis; staminate removed from each cluster; left uncovered...	7	130	56	$2.23 \pm .24$	.0600
Corollas removed from pistillate; staminate undisturbed; exposed to open pollination.....	5	90	69	$2.56 \pm .29$	.0840
Staminate removed; pistillate exposed to open pollination.....	4	40	80	$3.32 \pm .32$	.1050
Staminate and pistillate undisturbed and exposed to open pollination....	4	40	81	$3.64 \pm .32$	.1050

fruit, and there was an average of $1.39 \pm .24$ nuts per pistillate flower exposed. On six trees, 70 pistillate flowers and the staminate flowers surrounding them, were enclosed in the wire screen envelopes. Of these 36 per cent set fruit and an average of $1.10 \pm .26$ nuts per exposed pistillate flower were produced. The difference in set between the two treatments is not significant. While small insects such as thrips and aphids could easily have reached the stigmas of the flowers in these tests, none were noted. It is most likely that pollination and resulting fertilization took place from pollen falling through the screen and onto the stigmas.

Since the corolla of a flower is thought to attract insects, the following experiment was made. The corollas were removed from 130 pistil-

late flowers just before anthesis, and all staminate flowers were removed from the clusters at the same time. The flowers were left exposed to open pollination; 56 per cent set fruit. There were on the average $2.23 \pm .24$ nuts per pistillate flower used in the experiment. A similar experiment was set up with the staminate flowers left undisturbed in the clusters. Ninety pistillate flowers on five trees were used; 69 per cent set fruit. On the average $2.56 \pm .29$ nuts were produced per flower exposed. The presence of staminate flowers in the cluster apparently increased the set of fruit, but the difference is not statistically significant at the .05 level. The set of fruit under these two treatments is much higher than under wire screen. Either some insects visited these flowers even though the corollas had been removed, or else the wire screens interfered to some extent with pollination by falling or wind borne pollen.

Forty pistillate flowers on four trees were left undisturbed except to remove the staminate flowers from each cluster. These were exposed to open pollination; 80 per cent of the flowers set fruit. There was an average of $3.32 \pm .34$ nuts per exposed flower. Another 40 pistillate flowers on four trees were left undisturbed, together with the surrounding staminate blossoms. This was comparable to general orchard conditions. Eighty-one per cent set fruit and the average number of nuts per pistillate flower in the test was $3.64 \pm .32$. This increase in set over that obtained when the corollas were removed must be attributed to insect pollination.

These tests indicate that some pollination in tung may take place without the aid of insects. The pollen may be carried by wind or may drop onto the stigma as it falls from a nearby anther. As the staminate flower falls from the tree it whirls like a top and may scatter pollen for some distance in all directions. However, the very poor set obtained under the muslin tent on all flowers not pollinated by hand or by bees, suggests that pollination by this means is rather limited. Undisturbed flowers exposed to bees, flies and other flying insects set such a significantly large number of fruits as to indicate that tung flowers are largely insect pollinated.

Controlled crosses made at the United States Field Laboratories for Tung Investigations are protected against contamination by two methods. The entire tree to be worked upon is covered by building a frame of two by four timbers over which a light grade of muslin is stretched. While considerable expense is involved, such tents make it possible to protect the flowers against loss by frost. This method also provides an easy means of obtaining large numbers of selfed seeds. Although, as has been pointed out, very little set may be expected under a tent from flowers not hand pollinated, to insure against contamination of controlled crosses, staminate flowers are removed from the clusters and the pistillate ones are bagged. The tent protects both the bags and the worker from the weather. The second method, when working on trees in the open, is to enclose the flowers in kraft paper bags. Although less convenient, this type of protection is satisfactory for use in making controlled crosses.

EFFECT OF AGE OF POLLEN ON FERTILIZATION

In making controlled crosses in tung it is often necessary to work with trees blooming at different dates or to carry pollen long distances. It is important to know how effective the pollen remains as the flowers age. A test was set up using pollen from flowers of four different ages. The flowers pollinated were all of the same age, just past anthesis. All pollinations on a given tree were made on the same day. Fifty-two flowers on five trees were pollinated with pollen from flowers that had been open 1 day. The anthers were beginning to shed pollen. The set was 100 per cent. The average number of nuts per flower pollinated was $4.37 \pm .38$. Seventy-six flowers on the same five trees were pollinated with pollen from flowers that had been open 2 days.

TABLE II—AGE OF POLLEN IN RELATION TO SET OF FRUIT

Age of Staminate Flowers Used in Pollination	Number Trees	Number Flowers	Fruits Set (Per Cent)	Average Number Nuts Per Fruit
One day after anthesis anthers beginning to shed	4	46	100	4.37
Two days after anthesis; anthers shedding freely..	4	40	90	3.88
Three days after anthesis; anthers beginning to shrivel.....	4	42	38	2.38
Four days after anthesis; anthers shriveled; flowers abscised.....	4	41	54	1.78
Error difference of two means.....				0.54
Least difference significant at .05.....				1.22
Least difference significant at .01.....				1.76

Pollen was shedding freely from the anthers. Ninety-three per cent of the flowers pollinated set fruit, and an average of $3.88 \pm .38$ nuts per flower pollinated were produced. Forty-two flowers on four trees were pollinated with pollen from flowers that had been open for 3 days. The anthers were beginning to shrivel. Thirty-eight per cent of the pollinated blossoms set fruit. There was an average of $2.38 \pm .38$ nuts per flower pollinated. On these four trees 41 flowers were pollinated with pollen from flowers that had been open for 4 days. These staminate flowers had been abscised from the pedicels and were shriveled. The percentage of fruit set was 54, and an average of $1.78 \pm .38$ nuts per flower pollinated were produced.

These data indicate a gradual decline in the efficiency of pollen of tung, beginning 1 day after anthesis and increasing as the staminate flower becomes older. The difference in nuts produced per flower pollinated by pollen from flowers that have been open 3 days and those open for 4 days is not significant but differences between any other two ages of pollen used are significant.

Under weather conditions that existed during the blossoming period of 1941 in the tung orchards of the Gulf Region, pollen from flowers that had been open 1 day and the anthers of which were beginning to shed pollen gave the best set of nuts. In making controlled crosses best results no doubt would be obtained most seasons if this age of flower were used as the source of pollen.

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Pollen Germination in the Avocado

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THE reasons for the erratic and unsatisfactory bearing of certain avocado varieties in California are not altogether clear though considerable work has been done on this problem. In the case of the most important variety, Fuerte, a temperature relation seems to have been established (3) in that bearing is poorest in the coastal regions, where lowest mean temperatures occur during the period of flowering and fruit setting. The suggestion naturally occurs that lack of viable pollen or poor viability and germination may be responsible for this behavior. The purpose of this study is to determine the viability of avocado pollen and its germination at relatively low temperatures.

Numerous attempts to germinate avocado pollen by ordinary techniques using sugar solutions were tried, but failure resulted in all cases even where other pollens germinated. This indicates that possibly some substance essential to the growth of avocado pollen was lacking. Moreover, the fact that avocado pollen was found to germinate on the stigmas of a number of other plants and that pollens from other plants germinated on avocado stigmas (Table I) further indi-

TABLE I—GERMINATION OF VARIOUS POLLENS ON AVOCADO STIGMAS AND OF AVOCADO POLLEN ON OTHER STIGMAS

Pollen	Stigma	Germination*
Apple	Avocado	+
Feijoa	Avocado	+
Passiflora	Avocado	+
Boysenberry	Avocado	+
Papaya	Avocado	+
Citron	Avocado	0
Hibiscus	Avocado	0
Avocado (Fuerte)	Feijoa	0
Avocado (Fuerte)	Apple	+
Avocado (Leucadia)	Papaya	+
Avocado	Citron	0
Avocado	Carnation	+
Avocado	Passiflora	+
Avocado	Sterculia	+
Avocado	Lily	0

* + Indicates one or more grains germinating distinct pollen tubes.

cates that the artificial medium lacked some essential substance or condition necessary to avocado pollen tube growth. Supplementary substances such as yeast extract, vitamin B₁, and crushed stigmas added to the sugar solutions, however, failed to cause pollen germination.

Satisfactory results were finally obtained, by germinating the pollen grains directly on stigmas, using a modification of the technique employed by Buchholz (1) and Chandler (2). The technique used was briefly as follows: Pollen was transferred to unpollinated, freshly matured stigmas. After a given time, in most cases about 12 hours, the pistils were collected, killed and fixed for about an hour in a solution of 100 parts of 70 per cent alcohol and 7 parts of commercial formalin. Staining was done on the slide with equal parts of saturated aqueous solution of light green and aceto-carmine for 10 minutes. The pistils were then rinsed quickly with 95 per cent alcohol and mounted in a

drop of glycerine, at which time pressure was applied to the coverslip to crush the pistils flat for better observation.

This technique is useful only as a qualitative indication of pollen germinability because of the varied environment provided for the grains on the highly papillose stigma. However, the data thus obtained on pollen temperature and storage tolerances may be useful to the horticulturist and the plant breeder. Furthermore, this method is adapted to pollen germination studies under conditions in the field. As in all such studies the data obtained merely indicate the germinability of the pollen and do not measure its effectiveness in fecundation.

The present studies have shown that avocado pollen germinates over a wide range of temperatures. Flowers kept at 40 degrees F for 150 hours before pollination produced pollen which germinated readily at the same temperature. Higher temperatures produced good germination. Since the temperature in the avocado growing areas in California during the bloom period seldom reaches 40 degrees F there seems little probability that low temperature is a factor in pollen germination under field conditions. However, the ultimate fate of the pollen tube and the functioning of the pollen nucleus at this low temperature is as yet undetermined.

Naturally pollinated flowers taken from trees in the field from localities where fruit set is usually light showed many pollen grains and a high percentage of germination on the stigmas indicating that adequate pollination and germination probably occur under field conditions in the coastal regions of Southern California.

Storage experiments have demonstrated that avocado pollen retains its viability for a moderate period of time. Pollen of the Leucadia variety germinated readily after storage for 32 days at 40 degrees F in a desiccator over calcium chloride. Under the same conditions Nabal pollen germinated after 89 days storage and in one experiment Fuerte pollen germinated after 153 days storage at 59 degrees F. The critical conditions for and time limits of pollen storage of the many avocado varieties are not known, but the data obtained in this study indicate that viability is not quickly lost in storage, a fact which may be decidedly helpful in breeding work.

SUMMARY

Investigations on avocado pollen indicate that it does not germinate in ordinary sugar solutions, but that the pollen is viable and will germinate on stigmas at temperatures of 40 degrees F and higher. This viability is retained for several weeks when the pollen is stored. Avocado pollen also germinates on stigmas of certain other plants and likewise other pollens will germinate on avocado stigmas.

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Commercial Hand Pollination Methods for Apples in the Northwest

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IN THE early stages of development of the apple industry in the Northwest, the variety list included many sorts which were self-fruitful, as Winter Banana and Gano. In following years many of these varieties gradually disappeared and were replaced by some which were highly self-unfruitful, as Winesap and Delicious. A serious pollination problem was thus introduced, which has been met in part by the development of artificial or hand pollination methods, and which is used principally with the Winesap and Delicious varieties. The methods which are presented in this paper have been worked out in practice as satisfactory over a period of 10 years and involve 1,000 to 5,000 acres of orchard.

Varieties which have proved satisfactory as pollenizers for Delicious and Winesap are Jonathan, Winter Banana, Yellow Transparent, Golden Delicious, and Rome Beauty. Delicious may be used for Winesap, but Winesap is unsuitable as a pollen source because of imperfect pollen and small pollen content. Other varieties which have proved unsatisfactory as pollen sources are Stayman and Arkansas Black.

Pollen is best collected at least 48 hours before it is to be used. Orchardists who have suitable early-blossoming varieties, such as Yellow Transparent, have found this variety useful so far as the time factor is concerned. In the absence of early varieties, pollen is secured from later-blossoming varieties grown in sections with earlier season of bloom. The anthers reach full size and approach maturity at about the time the blossoms are ready to open, commonly referred to as the balloon stage (Fig. 1). Since the anthers dehisce and shed their pollen soon after they are full-grown, the pollen is collected promptly during this stage. It has been found that pollen allowed to remain on the tree as long as possible gives the best results.

In the early development of commercial hand pollination methods for apples, pollen was collected from blossoms containing opening anthers. The pollen was collected in glass tumblers or similar containers from which it was placed directly onto the blossoms. Because this method was slow it was soon replaced by another. Spurs containing blossoms in the pre-opening stage were collected in picking bags. These were emptied onto tables around which sat so-called "extractors"—men, women, boys and girls—who removed the anthers from the blossoms. Tables were first set up in packing sheds and other convenient places. Because of the delay in getting the blossoms to the extractors after removal from the tree and the resulting limpness of the blossoms, which complicated removing the anthers, the tables were moved into the orchard.

Removing small branches instead of spurs was also soon adopted as a practice by some collectors to aid in keeping the blossoms fresh. Some growers now delay pruning a few trees until time to collect pollen. These they prune at that time, taking pollen from the prunings.



FIG. 1. Left: apple blossom in "balloon stage". Collection may start at this stage and continue until the first anthers dehisce. Right: apple blossom past the pollination stage. All anthers have dehisced.

To further reduce wilting and thus facilitate rubbing out the pollen a method was next devised for each individual collector to extract the pollen at the time he gathered the blossoms. A wide-mouthed pint fruit jar with a piece of screen substituted for the cap was fastened to the belt of the collector by means of a wire hook attached around the neck of the jar. In practice, the collector picked only the blossoms which were in the right stage of development and rubbed out the pollen immediately into the jar.

Another method which eliminates the necessity of setting up a table in the orchard, was to spread a blanket on the ground onto which the blossom-bearing branches were placed. The extractors were seated on the ground and rubbed out the pollen into the wire-covered jar. A quart jar, being taller, was found more convenient than a pint jar for holding when one is sitting on the ground, so that the larger jar was often used.

When collection was first established on a commercial basis, ordinary house screen was used for extracting. With the blossom-bearing branches or spurs in one hand, each blossom was removed individually with the other. The face of the blossom was rubbed against the screen so that the anthers dropped through the screen into a convenient box. Pasteboard box lids were often used. Little wooden frames with screens attached and paper trays folded of heavy paper were also used. Anchoring the screen and frame to the table eliminated the necessity for holding the frame with one hand when rubbing out pollen with the other.

It was soon found that ordinary house screen was too fine and necessitated extra rubbing. Another disadvantage was that some of

the anthers failed to drop through the screen, particularly with varieties having large anthers. At the present time eight-mesh wire cloth is being used generally. Some growers report that even coarser screen may be used to advantage. The coarser screen, by minimizing the amount of rubbing, speeds up collection. The debris that filters through is screened out as the pollen is placed into curing trays.

When the pollen is collected it is "green". It must be ripened and cured. It is taken from the extraction table almost as rapidly as it is collected. Some growers follow the practice of collecting from the extractors every half hour.

The green pollen is then placed in small curing trays. These may be hand-folded paper trays or lids of pasteboard boxes of convenient sizes. The pollen is spread about $\frac{1}{8}$ -inch deep in the trays.

The temperature at which the pollen cures apparently is of considerable importance; 68 to 70 degrees F seems to be most satisfactory. If higher, the germination of the pollen may be reduced. If lower, the ripening of the pollen is delayed so that not only may the germination of the pollen be reduced but also the time at which it can be used is postponed. It is not advisable to attempt to shorten the curing time of approximately 48 hours. When the pollen is cured and is ready for application, the pollen dust may be seen on the sides of the tray.

Rooms of various descriptions are used for curing. Parts of old packing sheds and bunk houses make suitable places with a little remodeling. Individual growers who collect pollen often cure it in their homes. In each case there must be means of providing heat and ventilation.

Pollination must be done when the blossoms are in the proper stage, which is when the anthers have started dehiscing. It will be found that in general the first anthers dehisce a few hours after the blossoms open. If the weather is hot preceding and during bloom, the anthers may start dehiscing before the petals unfold. On the other hand if the weather is cool, the blossoms may be well opened before any anthers have dehisced. A general rule stating how long pollination may be done after the blossoms open cannot be made, but probably it should be completed by the time all anthers have dehisced (Fig. 1).

As soon as the number of receptive blossoms on the earliest trees equals the number of fruits the tree should bear, pollination is begun. Due to the shortness of the pollinating season, it is sometimes advisable to start on the south side of the tree, before the north side is ready.

The pollen is usually applied with a No. 4 pig-hair brush. Some growers prefer a No. 5 brush because it is easier to touch all parts of the pistil with the larger brush. Those who prefer the large brush do so on the theory that the cost of the pollen is one of the smallest items in the entire operation, applying the pollen costing more than the pollen itself. Others prefer a smaller brush because less pollen is used.

In an attempt to produce a wide flat surface at the end of the brush with which all parts of the pistil can be touched easily, some growers cut the ends of the bristles off squarely. These are then held together by a rubber band placed about $\frac{1}{4}$ -inch from the tip. By flaring out the ends of the bristles, a flat surface about $\frac{3}{8}$ -inch in diameter can

be produced on a No. 4 brush.

In the early stages of hand pollination, some growers used a penny lead pencil. Others used the tip of the finger. These methods, although slower, made it possible to do the work with a small amount of pollen.

During the process of applying the pollen to blossoms which are shedding pollen, some undesirable pollen is inevitably taken into the bottle by the brush. Should the pollinator use from the same bottle of pollen for a long period, as a whole day, he would dilute it with valueless pollen. Accordingly, only $\frac{1}{2}$ -ounce or enough to last a couple of hours is used at a time.

A glass tube 5 or 6 inches long and 1 to 2 inches in diameter, such as an insect collecting tube, makes a satisfactory container for carrying the pollen when it is being applied. For convenience, the tube may be placed in the shirt pocket, fastened by a paper clip attached to a rubber band around the top of the tube. A light cotton stopper may prevent loss of pollen in case the tube is accidentally inverted.

It is necessary to follow a system when going over the tree much the same as is done in thinning. Otherwise the pollinator may skip some parts and give others a double dose. Each worker establishes his own system. An experienced pollinator can pollinate a mature tree (20 feet tall and 40 feet spread) in about 45 minutes, using from 2 to 4 ounces of pollen per acre.

The actual placement of the pollen on the blossom requires special care. The experienced pollinator knows that there are five parts to the pistil and that at least one pollen grain must be placed upon each part if a properly-shaped apple is to result. With the relatively small surface on the end of the brush, it is very easy to miss part or all of the pistil. A large brush, obviously reduces this risk. Pollinators improve with experience. Girls and women are usually more efficient than men, and all are more efficient the second year than the first.

In order to make certain that all parts of the pistil are touched, some workers make two hits, one to "make aim" and the other to actually apply the pollen. An approach directly into the blossom seems to give best results. If the approach is from the side, the stigma on the far side may easily be missed. The number of blossoms to be pollinated on each tree depends upon such factors as wind, temperature, available labor, proximity to natural sources of pollen, and insect activity.

Ordinarily, insects are not relied upon for spreading the pollen from hand-pollinated blossoms to other blossoms although in the hand pollinating process thousands of grains of pollen are applied to each blossom. Pollen placed upon the blossom apparently deteriorates rapidly. However, insects working busily at the time pollen is being applied by hand doubtless spread some pollen.

The pollen should be kept relatively dry and loose. When holding it until the blossoms reach the right stage for pollination it should not be placed in a tightly stoppered vessel.

The benefits from commercial hand pollination of apples have been variable. In seasons when insect activity during blossoming has been poor and in orchards where natural sources of pollen are scarce, yields have been increased enormously.

Studies on the Cytology of *Vaccinium* Species

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ABSTRACT

This material will be published in full in the *American Journal of Botany*.

THE chromosome number of many additional species and varieties of blueberries has been determined. The three chromosome groups reported by Longley were confirmed and many species added to the diploid and tetraploid groups. The following species were found to be diploid: *Vaccinium crassifolium*, *V. elliottii*, *V. angustifolium* (forma *lanceifolium*), *V. caesarensense*, *V. sp. ?* (an evergreen highbush of north Florida), *V. darrowi*, *V. torreyanum*, and *V. tenellum*. The species *V. virgatum*, *V. brittonii*, *V. arcostaphylos*, and *V. simulatum* were found to be tetraploid, and both *V. amoenum* and *V. constablaei* were found to be hexaploid. Two additional records of Longley are here reported: *V. parvifolium* diploid and *V. asama* hexaploid.

Many of the species are arranged into series of diploid and tetraploid forms and, in several cases, into related diploid, tetraploid, and hexaploid series. Examples of these are (a) *V. angustifolium* (2x), *V. pennsylvanicum* (4x); (b) *V. darrowi* (2x), *V. myrsinites* (4x); (c) *V. caesarensense* (*corymbosum* in part) (2x), *V. australe* (*corymbosum* in part) (4x); and (d) *V. tenellum* (2x), *V. virgatum* (4x), and *V. amoenum* (6x). In general, the tetraploid species are taller, more vigorous, have larger leaves, flowers, and berries, and sucker less than their corresponding diploid species. The hexaploids of the *tenellum-virgatum-amoenum* series and the series ending in *V. constablaei* are the tallest and most vigorous so far as the material studied is concerned. Their flowers and fruits are largest and in the *tenellum-virgatum-amoenum* series at least the plants sucker the least.

So far no triploid blueberries have been found. One vigorous pentaploid similar to *V. amoenum* was collected in the wild in southeastern Georgia. Vigorous pentaploids similar to the foregoing have been obtained with ease from crossing *V. australe* (4x) with *V. ashei* (rabbit-eye) (6x). Fruit on plants from such crosses made by Coville is nearly seedless. Many species having the same chromosome number have been crossed by Coville and Freeman, and all the resultant seedlings of these crosses observed by the present authors have been fertile.

Observations throughout Eastern United States indicate that most of the species having the same chromosome number hybridize freely wherever the plants grow near each other. The following diploid hybrids have often been observed in nature: *V. elliottii* x *V. darrowi*, *V. elliottii* x *V. atrococcum*, *V. tenellum* x *V. darrowi*, *V. tenellum* x *V. pallidum*, *V. atrococcum* x *V. torreyanum*, *V. atrococcum* x *V. caesarensense*, *V. angustifolium* x *V. canadense*; and among the tetraploids, *V. myrsinites* x *V. australe*, *V. myrsinites* x *V. arkansanum*, *V. pennsylvanicum* x *V. corymbosum*, *V. pennsylvanicum* x *V. brittonii*.

These hybrids back-cross readily with the parental species. Where similar hybridizations have been made under controlled conditions the offspring resemble those found in the wild.

Breeders now have many more characters to use in their work. For example, each species of the *tenellum-virgatum-amoenum* series and the related rabbiteye varieties are notably drought and heat resistant, and are better adapted to upland conditions than are present highbush varieties. Other species also have characteristics that seem to be of value to the breeder.

Rest Period Requirements for Blueberries

By GEORGE M. DARROW, *U. S. Horticultural Station,
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ALTHOUGH most of the varieties of highbush blueberries originated in New Jersey, extensive plantings of them have been made in North Carolina, and recently several plantings have been made in Georgia and other Southern States. Coville emphasized the need of a low temperature period to start growth of the blueberry. Reports of tests of the highbush varieties in Florida have consistently indicated failure of the plants to grow. It therefore seemed worthwhile to test the length of the rest period requirements of the standard highbush blueberry varieties in comparison with the "rabbiteye" blueberry which is native in north Florida.

In 1939-40 ten vigorous plants in 8-inch pots of each of 12 varieties and two selections of the highbush and one variety of the rabbiteye blueberry were tested for their rest period requirements. The plants were kept in an outdoor bed while being exposed to cold for a definite period. Two plants of each variety were taken into the greenhouse at each date: October 15, November 15, December 15, January 15, and February 15. They were left in the greenhouse until April and then placed for the summer in the outdoor bed. The early part of the autumn of 1939 was fairly mild and the latter part cold, there being 284 hours of cold below 45 degrees F from October 15 to November 15, and 266 hours above 50 degrees F. For the November 15 to December 15 period there were 511 hours below 45 degrees and 111 hours above 50 degrees.

In this preliminary test the plants of the rabbiteye variety, "Pecan",¹ taken in on October 15 did not start well, but the November 15 (and later date) plants started growing vigorously soon after being placed in the greenhouse.

None of the plants of highbush varieties in the October 15 or November 15 lots started at all during the entire period in the greenhouse and not a bud started on these plants for several weeks after being placed out-of-doors in April. By the end of July, however, all plants of these October 15 and November 15 lots started vigorous growth and by September were apparently normal plants. The December 15 group of plants of the highbush varieties all showed more or less growth of flower buds. Vegetative buds with some varieties, such as Cabot, grew freely and others more slowly. Plants in this December 15 lot seemed to be on the border line of completion of their rest period. The January 15 and February 15 plants started flower and vegetative growth promptly in the greenhouse and apparently had their rest period fully broken when brought in.

From this preliminary work, it seemed best to repeat the tests in the season of 1940-41, but to test the varieties on the basis of the number of hours the plants were exposed to temperatures of 45 degrees

¹Thus labeled by the late F. V. Coville and recorded as coming from Crestview, Florida.

F or below before being subjected to growing temperatures in the greenhouse. The calculated number of accumulated hours of temperatures below 45 degrees for the 1939-40 lots were: October 15, 30 hours; November 15, 314 hours; December 15, 825 hours; and January 15, 1,400 hours. Therefore for the 1940-41 series fewer to more than 314 hours of cold were selected for the rabbiteye, and fewer to more than 825 hours for the highbush varieties, as likely to be the most informing on growth response resulting from chilling.



FIG. 1. Rancocas blueberry plants taken into the greenhouse on October 30 (left) after 100 hours of temperatures below 45 degrees F, and on January 2 (right) after 1,060 hours of cold, below 45 degrees F. The October 30 plant still retains its old leaves and has not started any new growth. The January 2 plant is in flower and has started new growth (Photo on Feb. 3).

ary 3, and of the highbush plants February 3 and March 3.

The number of flowers and vegetative-buds that started growth was recorded on February 3, and the same records plus number of fruit-buds that had started were taken on March 3 (see Table I). February 3 was too early to get a completed record on all varieties, especially for the lots with 950 and 1,060 hours of cold. Many more buds started later, and March 3, 2 months after the last lot was brought into the greenhouse, seemed to be about the right date for taking the final records.

Ten large plants in 8-inch pots (see Figs. 1-3) of each of 13 varieties and two selections of the highbush and one variety of the rabbiteye blueberry were used in the 1940-41 tests. The plants were left in an outdoor bed until they had been exposed to the required number of hours below 45 degrees F. Plants of the rabbiteye variety, "Pecan", were exposed to 100, 150, 200, 250, and 360 hours of cold. Plants of the highbush varieties were exposed to 500, 650, 800, 960, and 1,060 hours of cold. The fall temperatures were very similar to those of 1939, there being 345 hours of cold below 45 degrees and 266 hours above 50 degrees by November 15, and 484 hours below 45 degrees and 122 hours above 50 degrees November 15 to December 15. Detailed records of the rabbiteye plants were taken Febru-



FIG. 2. Plants of the Stanley blueberry, having been exposed to 650 hours of cold (left) and to 800 hours of cold (right). Stanley seems to require about 800 hours of cold below 45 degrees F before its rest period is broken (Photo taken Feb. 3).

The records for average number of flowers, fruit-buds and shoot-buds per plant for the 13 varieties of highbush blueberries are given



FIG. 3. Plants of Cabot blueberry, having been exposed to 800 hours (left), 650 hours (center), and 500 hours (right) of cold below 45 degrees F before being placed in the greenhouse. The plant at the left, having 800 hours of cold, has already made new growth and is in blossom (Photo taken Feb. 3).

TABLE I.—THE EFFECT OF LENGTH OF REST PERIOD ON THE STARTING OF BLUEBERRY PLANTS

Record of	500 Hours Below 45 Degrees F Nov 28				650 Hours Below 45 Degrees F Dec 5				800 Hours Below 45 Degrees F Dec 15				950 Hours Below 45 Degrees F Dec 23				1060 Hours Below 45 Degrees F Jan 2			
	Flowers Open		Buds Started		Flowers Open		Buds Started		Flowers Open		Buds Started		Flowers Open		Buds Started		Flowers Open		Buds Started	
			Fruit	Shoot			Fruit	Shoot			Fruit	Shoot			Fruit	Shoot			Fruit	Shoot
Section A*																				
Feb 3.....	10		2		12		4		35		11		24		11		56		9	
Mar 3.....	23	8	3		29	8	7		139	25	25		216	35	32		271	47	33	
Section B†																				
Mar 3.....	61	17	7		33	8	15		158	31	36		132	27	35		222	46	38	
Section C‡																				
Mar 3.....	7	2	2		27	7	5		131	23	20		254	37	30		293	48	30	

*Data for 13 varieties of highbush blueberries.

†Data for the Weymouth, Wareham, Rancocas and Cabot varieties of highbush blueberries.

‡Data for Stanley, Dixi, Pioneer, Rubel, Scammell, June, Burlington, Concord, and Jersey varieties of highbush blueberries.

in Table I. Since shoot growth seemed the best criterion of sufficient chilling, grade values based chiefly on the number of shoots starting were assigned to the individual varieties. These values for each variety for each chilling period are given in Table II.

TABLE II—VARIETIES OF BLUEBERRIES, 1 RABBITEYE AND 13 Highbush, LISTED IN ORDER OF THEIR 1940-1941 GROWTH RESPONSE TO DIFFERENT PERIODS OF CHILLING (VALUES FOR GRADE NUMBERS GIVEN BELOW)*

Variety	Exposure Period to Chilling Below 45 Degrees F (Hours)				
	500	650	800	950	1060
Weymouth.....	2	3	4	5	5
Rancocas.....	2	3	4	5	5
Wareham.....	2	3	4	5	5
Cabot.....	1	3	4	4	5
Stanley.....	2	2	4	4	5
Dixi.....	1	2	4	5	5
Pioneer.....	1	2	3	4	5
Rubel.....	1	1	5	5	5
Scammell.....	1	1	4	4	5
June.....	0	1	4	4	5
Burlington.....	0	1	4	5	5
Concord.....	0	1	3	4	5
Jersey.....	0	0	4	4	4
	100 hours	200 hours	240 hours	360 hours	—
Pecan.....	0	0	0	5	—

*Values for grade numbers:

0 = no shoot growth—often some flowers—see Cabot in Fig. 3, right.

1 = slight shoot growth (1 to 15 shoots)—with some flowers—see Stanley in Fig. 3, center.

2 = medium shoot growth—often many flowers.

3 = much shoot growth—but not equal to number 4—see Cabot in Fig. 3, left.

4 = full shoot growth—but not full flowering.

5 = full shoot growth—and full flowering—see Stanley in Fig. 2, left.

For the rabbiteye variety, "Pecan", 200 hours of chilling was not sufficient for any new shoot growth, yet after 250 hours the plants seemed to have fully finished their rest period. A few shoots started after 500 hours of chilling on some varieties of the highbush and after 650 hours a good many shoots on a few varieties. However, it is evident that 800 hours of chilling was the minimum for good growth under the conditions of this test, while 1,060 hours seems to have been enough for all varieties except possibly the Jersey.

Four varieties, Weymouth, Rancocas, Wareham, and Cabot seemed to have partially finished their rest period after 650 hours of chilling (see Table I-B). These four varieties had 15 shoots per plant after 650 hours as compared with 20 shoots for the other nine varieties after 800 hours of cold. However, even these four varieties grew much better after 800 hours of chilling. They are probably the best varieties for trial at the southern limit of blueberry growing. In general, the highbush blueberry varieties respond to cold about as do ordinary peach varieties and need about the same amount of chilling. Possibly this blueberry is helped more than the peach by an additional period of cold beyond 800 hours. Other species of blueberries which cross with the highbush are native to north Florida so that it should be possible to obtain hybrids fully adapted to the short cold period that obtains there.

Field experience agrees, in general, with these experiments. High-

bush varieties do not get enough cold in southern Georgia in the average winter to make a normal growth and usually die without producing any fruit. However, the rabbiteye variety, "Pecan", required less than one-third the cold period that the highbush varieties did, and is far better adapted to regions like southern Georgia and northern Florida than are the highbush varieties. It corresponds to the Peento peach in having a slight cold requirement for breaking the rest period. Other rabbiteye varieties may have shorter or longer winter rest requirements than does the "Pecan". The highbush is native to north Florida, and varieties adapted to north Florida conditions can undoubtedly be derived from selected wild plants crossed with northern sorts.

Effect of Renovation of Beds After Harvest on Yield and Grade of Strawberries¹

By E. B. MORROW, *North Carolina Agricultural Experiment Station, Raleigh, N. C.*, and GEORGE M. DARROW, *U. S. Horticultural Station, Beltsville, Md.*

OBSERVATIONS of the cultural practices used by strawberry growers in the commercial areas of Eastern North Carolina over a period of years have indicated the need for more specific information on plant spacing, age and size of plant, and renovation of beds after harvest. A preliminary study by Morrow and Beaumont (1) of the time of rooting runner-plants indicated the value of early-formed plants for greatest yields during the first fruiting year. Working with spaced plants of the Blakemore, Klondike, and Missionary varieties, they found that runner plants rooted in early summer produced the greatest number of flowers and fruits per plant but that the average berry size was smaller than on late-rooted plants. Later, Morrow and Darrow (2) reported that 2-year-old plants had a larger number of leaves per plant at the end of the growing season and produced more flowers and fruits the following spring than runner plants rooted during June, July, and August before the first fruiting year. These studies led to the initiation of more extensive experiments on age and size of plant and on renovation of beds after harvest. The results on renovation during the 1938 and 1941 fruiting seasons are presented herewith.

METHODS

In all trials the experimental unit was a single 50-foot bed, and the plots were arranged in systematic order. In 1938 the plots were replicated three times and in 1941 four times. The 1938 beds were 42 inches and the 1941 beds 48 inches from center to center. The different spacing treatments appeared as in Fig. 1 prior to renovation.

Renewal of the beds was started as soon after harvest as soil moisture conditions permitted. This meant during the first half of June in both 1937 and 1940. In the renewal of the triple-row bed, both side rows were plowed up. In the matted row, a portion of the bed was plowed up on each side, leaving a strip of plants 6 to 8 inches wide.

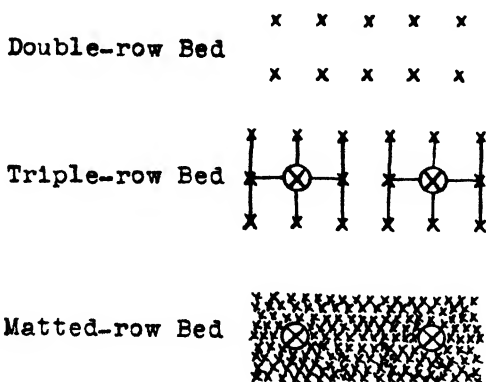


FIG. 1. Appearance of strawberry beds before renovation.

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The double row was renewed by taking out two of every three plants in each of the rows making up the double-row bed. In each case, approximately two-thirds of the old plants were destroyed. Renewal was accomplished by re-forming the original beds with new runners. The methods of renewal were as similar to usual grower practice as the arrangement of plots would permit. The beds were fertilized in September and December, in accordance with the usual practice. The 1941 experiment comparing renovated, old, and young beds of both Blakemore and Fairmore was confined to triple-row beds. The renovated beds were renewed

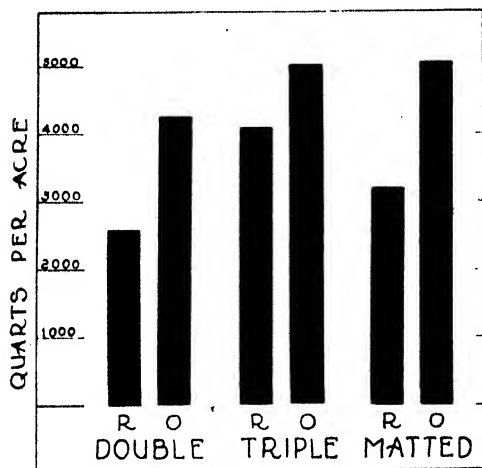


FIG. 2. Total yields from renovated (R), and 2-year-old (O) beds, 1938.

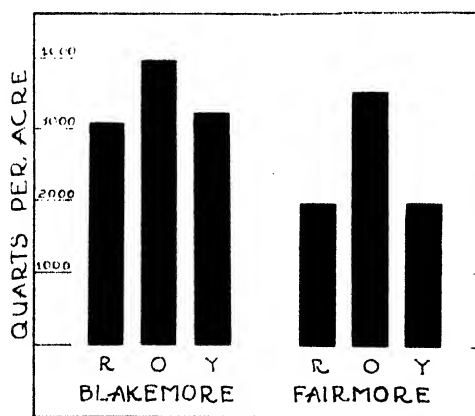


FIG. 3. Total yields from renovated (R), 2-year-old (O), and 1-year-old (Y) beds, 1941.

as indicated above for the triple row, while in the old beds all of the plants were left to fruit for a second season. In the young beds approximately a full stand of plants was obtained by July 15 of the 1940 season. Runner production on the old plants in the renovated bed was not sufficient to give a full stand of new plants under any spacing treatment. The old plants of Blakemore produced more new runners than the old plants of Fairmore.

RESULTS

The data were analyzed by the usual methods of analysis of variance, and since the plots were systematically arranged, the 1 per cent level of significance has been adhered to.

The results are presented in the accompanying graphs. The 1938 total yield from old beds was significantly greater than from renovated beds for the Blakemore variety on all three spacing treatments (Fig. 2). The total yield was 61 per cent greater on the old double-row, 22 per cent greater

on the old triple-row, and 57 per cent greater on the old matted-row than on renovated beds. The 1941 yields from renovated, from 2-year-old, and from young beds again gave significant differences in favor of the 2-year-old beds for both the Blakemore and Fairmore varieties (Fig. 3). For Blakemore, the old beds produced 40 per cent more berries than the renovated beds and 32 per cent more than the 1-year-old beds. For Fairmore, the yield was 69 per cent greater on the old beds than on either the renovated or 1-year-old beds. The 1941 trials were confined to triple-row beds. On the younger plants, the berries were larger and the percentage of No. 1 berries was greater than for the old beds (Fig. 4). The differences in size and grade of berries were not enough, however, to make up for the considerably lower yield in comparison with the old beds. It is possible that the size of berry on the old plants might have been increased by fertilizing at rates proportional to the number of leaves per plant or per unit of leaf area. Fertilization was at the same rate per acre regardless of spacing or renovation treatments.

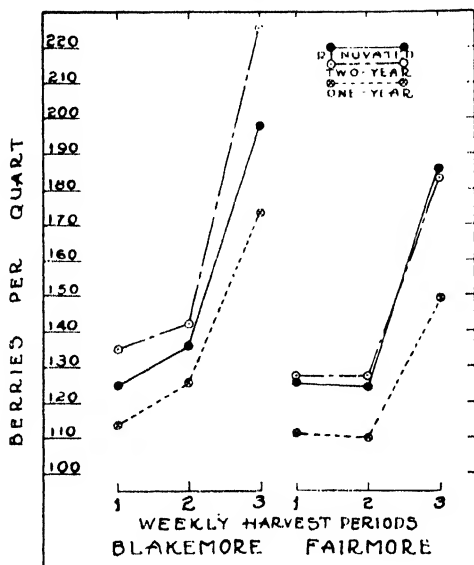


FIG. 4. Number of field run berries per quart, 1941.

berries were larger and the percentage of No. 1 berries was greater than for the old beds (Fig. 4). The differences in size and grade of berries were not enough, however, to make up for the considerably lower yield in comparison with the old beds. It is possible that the size of berry on the old plants might have been increased by fertilizing at rates proportional to the number of leaves per plant or per unit of leaf area. Fertilization was at the same rate per acre regardless of spacing or renovation treatments.

SUMMARY

Data are presented on the renovation of strawberry beds previous to the 1938 and 1941 fruiting seasons. Two-year-old beds produced greater yields than renovated beds in both years. The 1938 yield for Blakemore was 61 per cent greater for the old double row, 22 per cent for the old triple row, and 57 per cent greater for the old matted row. In 1941 the 2-year-old beds outyielded both renovated and 1-year-old beds for Blakemore and Fairmore. The berries were larger and the percentage of No. 1 berries was greater on the 1-year-old plants. The differences in size and grade were not enough, however, to make up for the considerably lower yields in comparison with the old beds.

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The Vitamin C Content of Small Fruits¹

By R. A. LINEBERRY and LELAND BURKHART, *North Carolina Agricultural Experiment Station, Raleigh, N. C.*

THE necessity of vitamin C in the human diet is well established. Small fruits such as strawberries, blackberries, and blueberries are among the first fruits to ripen in the spring, and hence, are a desirable source of vitamin C following the winter when other fresh fruits are becoming limited in quantity. North Carolina produces large quantities of these fruits and it was thought advisable to investigate their vitamin C content.

The sampling method employed in this investigation for the determination of vitamin C was developed and described by the authors (1). The fruit tissue was extracted with a mixture of 4 per cent metaphosphoric acid and 8 per cent acetic acid by means of a motor-driven emulsification blender. One minute was required for this, which was more efficient than the mortar and pestle method of grinding with sand. The extract was centrifuged and duplicate aliquots were titrated immediately with an electric titrimeter (4), using sodium 2, 6-dichlorobenzenoneindophenol of known ascorbic acid value as an indicator.

It was found (1) that the vitamin C content of the strawberries varied with growing conditions. Berries ripened in the sun had a higher vitamin C content than shade-ripened berries. Berries of different ripeness varied greatly. Different samples from commercially picked quarts were relatively variable. Berries from different parts of the same field and from different fields were also variable. For Klondike berries from different parts of one field the range was from 41.0 to 49.3 milligrams per 100 grams of fruit; and from different fields, 37.0 to 51.9 milligrams per 100 grams of berries.

There was also considerable varietal difference, Fairmore having the highest vitamin C content, Missionary the next, Massey the next, and Blakemore the lowest. However, duplicate samples of the same variety carefully selected for the same conditions as to location, time, degree of maturity, exposure to sunshine, and size of fruit showed close agreement in vitamin C content, rarely varying as much as 2 per cent. Satterfield and Yarbrough (6) in North Carolina also found Fairmore to have the highest vitamin content of the varieties they examined. The mean of the samples for Fairmore was 69.5 milligrams per 100 grams of fruit and for Blakemore 32.6 milligrams. Kirk and Tressler (5) reported a range of 40 to 104 milligrams per 100 grams for the 11 varieties they tested in New York State. Daily variations were reported by these investigators for some of the varieties. The ascorbic acid values of the Dorsett variety varied from 32 milligrams to 78 milligrams per 100 grams of fruit during a 2-day period. The Fairfax variety showed a variation of 102 milligrams to 40 milligrams of ascorbic acid per 100 grams of fruit during 1 week. The specific

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TABLE I—ASCORBIC ACID CONTENT (MILLIGRAMS PER 100 GRAMS OF FRUIT)
OF THE FRUIT OF DIFFERENT VARIETIES OF BLUEBERRIES (A AND B
REPRESENT DUPLICATE SAMPLES OF ONE PINT EACH)

Variety	A	B	Mean
	(Milligrams)	(Milligrams)	(Milligrams)
Cabot.....	18.2	19.0	18.6
Rancocas.....	18.2	18.6	18.4
Scammell.....	16.4	16.7	16.5
Concord.....	16.0	16.1	16.0
Scammell (green).....	3.6	3.0	3.3

conditions associated with these large variations were not accounted for.

Strawberries grown in direct sunshine were consistently higher in ascorbic acid than those ripened in shade (1).

Blueberries (Table I) contain less ascorbic acid than strawberries but not much difference was found among the six varieties of blueberries tested. In this connection Fellers and Merriam (2) also found only small differences in ascorbic acid content of cultivated blueberries grown in Massachusetts. Kirk and Tressler (5) found a range of 12 to 20 milligrams for different varieties in New York State. It is of interest to note that green Scammell blueberries contain very small amounts of ascorbic acid while the ripe fruits contain considerable amounts.

The ascorbic acid values of three varieties of raspberry, two of blackberry, and three of dewberry, as indicated in the Table II are much

TABLE II—ASCORBIC ACID CONTENT (MILLIGRAMS PER 100 GRAMS OF FRUIT)
OF THE FRUIT OF RASPBERRIES, DEWBERRIES, AND BLACKBERRIES (A AND
B REPRESENT DUPLICATE SAMPLES OF ONE QUART EACH)

Variety	A	B	Mean
	(Milligrams)	(Milligrams)	(Milligrams)
Young (Dewberry).....	34.0	31.0	32.5
Boysen (Dewberry).....	24.0	27.8	25.9
Lucretia (Dewberry).....	24.0	30.0	27.0
Dixie (Raspberry).....	33.0	32.0	32.5
Latham (Raspberry).....	24.0	23.1	23.5
Newburgh (Raspberry).....	20.0	21.0	20.5
Early Wonder (Blackberry).....	23.0	24.0	23.5
Brainerd (Blackberry, ripe).....	12.8	13.0	12.9
Brainerd (Blackberry, red stage).....	11.2	12.0	11.6

higher than those for blueberries. However, the Brainerd blackberry has a low ascorbic acid value. Greater varietal differences in ascorbic acid content were obtained in raspberries and dewberries than in blueberries. Moreover, the duplicate samples of Boysen and Lucretia dewberries were relatively variable. For New York, Kirk and Tressler (5) report a range of 13 to 29 milligrams for seven varieties of raspberries. However, only small daily variations within a variety were found, which was very much in contrast to the large daily variations found in strawberries. Low values were reported for dewberries (5); whereas the values for the dewberry varieties shown in Table II compare in magnitude with those for raspberries.

SUMMARY AND CONCLUSIONS

Ascorbic acid in small fruit tissue was efficiently extracted in 1 minute with a metaphosphoric acid mixture in an emulsification blender.

Strawberries showed considerable varietal differences as to ascorbic acid content, which ranged from 32 milligrams to 66 milligrams per 100 grams of fruit. The varieties ranked in the following descending order: Fairmore, Missionary, Massey, and Blakemore. The ascorbic acid content of Klondike strawberries was markedly affected by the environment, especially by sunshine and by field location.

Blueberries contained less ascorbic acid than strawberries, but not much difference was found between varieties. Green fruit of blueberries contained only a trace of ascorbic acid. Three varieties of dewberries were found lower in ascorbic acid than most strawberry varieties, but higher than blueberries. Brainerd blackberry, low in ascorbic acid, was found to contain only 12 milligrams per 100 grams of fruit.

The ascorbic acid content of the raspberry varieties analyzed was similar to the values obtained for dewberries and ranged from 20 to 33 milligrams per 100 grams of fruit.

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Examples of Incompatibility between Grape Varieties and Rootstocks

By H. E. JACOB, *University of California, Davis, Calif.*

VINIFERA grape varieties are grafted on to special rootstock varieties to combat phylloxera, *Phylloxera vitifoliae* (Fitch), or nematodes, mainly rootknot nematode — *Heterodera marioni* (Cornu). Where neither of these pests is present, own-rooted vines are used. The resistant rootstocks are selected varieties of native American species of *Vitis*, or hybrids of two or more American species, or of one or more of the American species with *Vitis vinifera*. By selection and testing, the least suitable stocks have been largely eliminated. Those retained graft readily to most of the fruiting varieties and the grafted vines of most combinations differ only in degree as to vigor, fruitfulness, and general performance. A few combinations, however, fail completely and the incompatible combinations cannot be predicted by any known means.

Judging from the number occurring in our own experiments, the records of European investigators undoubtedly contain numerous examples of incompatible combinations but not many appear in publications readily available to investigators in the United States. Bioletti, Flossfeder, and Way (1) mention two — Black Corinth and White Corinth on *Riparia* x *Berlandieri* 420-1 — occurring among 151 scion-stock combinations. Husmann, Snyder, and Husmann (5) do not report a single instance of uncongeniality in summarizing information on 3,410 vinifera-stock graft combinations involving 311 vinifera grape varieties and 105 rootstock varieties. Furthermore, they report successful grafts of Panariti — presumably the same as the Black Corinth used by Bioletti, Flossfeder, and Way (1) — on the *Berlandieri* x *Riparia* 420-A stock. Branas (2) states that the *Riparia* x *Berlandieri* 420-A lacks affinity for Merlot. Rives (9) reports the Dattier on *Riparia* x *Rupestris* 3309 to be dead or very much stunted within two years after field grafting. The correctness of this observation has been partially confirmed by a test made at Davis in which only two vines were alive at the end of one year from 100 that were field budded in 1937. Again, however, Husmann, Snyder, and Husmann (5) report on five vines of this combination that were maintained in good condition for 21 years or longer. Gervais (3) reports that numerous vines of Terret-Bourret on *Riparia* Gloire and *R. Scribner* declined rapidly. Paulsen (7) states that Catarratto grafts (vines) on *Mourvedre* x *Rupestris* 1202, *Riparia* x *Rupestris* 101-14, *Rupestris* Martin, *Gamay Couderc*, and *Aramon* x *Rupestris* No. 2 die (by folletage) in the first or second year; Perricone grafts on 1202, 101-14, and *Rupestris* Martin perish in the first or second year; and that the stocks 1202, 101-14, *Rupestris* Martin, *Gamay Couderc*, *Aramon* x *Rupestris* No. 2, *Riparia* x *Rupestris* 3306, and 3309 should not be used for Inzolia. Guicherd (4) reports that the affinity of Genouillet with *Riparia* is insufficiently good and Pacottet (6) says that Alphonse Lavallee grafts poorly with the *Aramon* x *Rupestris*. Perold (8) claims

bad affinity of *Aramon* x *Rupestris* No. 1 for Muscat of Alexandria and also states that odd vines of Muscat of Alexandria on *Mourvedre* x *Rupestris* 1202 die suddenly during the first four years. In the experiment vineyards at Davis a lot of 20 bench grafts of Muscat of Alexandria on *A* x *R* No. 1 was planted in 1928. The tops (scions) of four of these vines were killed by an early freeze in the fall of 1930. The four vines were replanted in 1931, and in 1942 all vines of the lot are in excellent condition. Also, 22 bench grafts of Muscat of Alexandria on 1202 were planted in 1930; after 12 years every vine is very vigorous and the crops have been excellent. These examples by no means exhaust the possibilities of the literature but by far the most of the reports on scion-stock compatibility are made in very general and not in specific terms. Some of the conflicting reports are perhaps the result of incorrect identity of some of the propagating material, especially the stocks.

In the investigational work carried on by the California Agricultural Experiment Station during the past 20 years, additional examples of serious degrees of incompatibility between certain fruiting varieties and certain stocks have been encountered. The work has included about 510 fruiting varieties but only 24 selected rootstock varieties of recognized merit. Only one or two stocks were used with many of the fruiting varieties, the vines being grafted for the sole purpose of establishing them in the vineyard or variety collections. In all, about 1,000 scion-stock combinations are represented. Bench grafting and field budding, principally the latter, have been the propagation methods used.

Emperor, Molinera (Red Malaga), Palomino, and Aramon have been failures on the stock variety *Berlandieri* x *Rupestris* 57-Richter. Not a single successful bench graft of these combinations has been obtained, yet buds of the same scion wood succeeded normally when placed on a number of other stocks. Each of these varieties has been field budded on to the 57-R stock and the buds grew fairly well for a short time, usually until about the middle of the summer of the year following the budding. All died by the end of the second summer. Lots 20 to 30 vines were used in the budding tests. The Emperor-57-R combination has been particularly interesting because successful bench grafts of the reciprocal combination 57-R on Emperor have been obtained. Alicante Bouschet grows well on the 57-R; Emperor grows on the Alicante Bouschet. Successful double grafts of 57-R on Alicante Bouschet on Emperor and of Alicante Bouschet on 57-R on Emperor have been made, but grafts of Emperor on Alicante Bouschet on 57-R failed. This latter double-graft combination has not been attempted by budding or field grafting.

Grenache on *Berlandieri* x *Riparia* 5-A (Teleki) grew well from field buds until the middle of the first summer. Toward fall the leaves became intensely red and by November most of the vines were dead. The scions were much enlarged at the unions; the diameter of the stocks had enlarged very little, if any; the unions were mechanically weak and broke apart easily.

Cortese and Barolo failed on *Aramon* x *Rupestris* No. 1 (Ganzin). The vines, established by field budding, grew fairly well during the

first season. In the second year, the growth of the Cortese on *A x R No. 1* was very weak and some vines died. The Barlo on *A x R No. 1* vines were weak after the second year but not quite so bad as the Cortese. All were removed the third year.

Tinta amarella on *Mourvedre x Rupestris 1202* (Couderc) became weak in the second year after field budding. The leaves became very red in late summer and no fruit matured. These also were removed the third year.

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Potassium Content of Grape Leaf Petioles and Blades Contrasted with Soil Analyses as an Indicator of the Potassium Status of the Plant¹

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THE concept of foliar diagnosis as an aid to the fertilization of crops was introduced by Lagatu and Maume (6) in France and more recently in this country by Thomas (9). Their concept has been adopted in part in the present study. The main difference is an assumption by the writer, that for a given plant part found suitable for analysis, there is a minimum value² (range) for each nutrient which characterizes a deficiency. Since there is in most instances only one dominant limiting nutrient or factor operating at a given moment, all other nutrients or factors are likely to be above the minimum value. This hypothesis eliminates the considerations involved in the "quality" and "intensity" of nutrition as postulated by Lagatu and Maume and by Thomas, and accordingly the preparation of the analytical results for interpretation is simplified, as only minimum values are of interest. This simplification does not alter the main purpose of plant tissue analyses, namely to disclose the need for a given nutrient by the plant, which is also the objective of plant tissue "quick tests" (1, 2, 4, 7, 11). In the present work the more accurate laboratory methods have been utilized to establish the basis for the rapid methods to be adopted ultimately in the field.

When a nutrient in a given plant part reaches a minimum value then it may be assumed that the demand for that constituent is greater than the supply or that the supply is equivalent to the demand. Under practical conditions, however, the latter condition seldom exists, since the supply is either in excess of requirements or inadequate to meet the demand. When a given nutrient is present considerably above the range of the minimum percentages, then it may be assumed that growth is limited at that particular moment by some other factor, which may or may not be corrected economically when it has been disclosed.

Soil analyses have been used extensively throughout the world to ascertain nutrient deficiencies. Under restricted conditions some methods have been correlated positively to plant responses, but under other

¹Conducted by the Division of Plant Nutrition and the Agricultural Extension Service of the University of California, in cooperation with the American Potash Institute, Mr. Jack Osborn and the Italian Vineyard Co. Mr. R. G. La Rue and Mr. Leo Kline ably assisted in getting the harvest records at Guasti and in the Alexander Valley, respectively. Additional assistance was furnished by the personnel of the Works Progress Administration Official Project No. 65-1-08-91-B-10.

²The minimum value of a nutrient may be affected by other factors as for example potassium by the presence of sodium. Comparable plant parts of tomato may contain 0.50 per cent K when displaying potassium deficiency symptoms in the absence of sodium, but with sodium this value may be reduced to 0.25 per cent, a decrease of 50 per cent in the minimum value. From the practical standpoint, however, these values would constitute a minimum range and plants in this category could be expected to respond to potassium applications under favorable conditions of growth.

conditions the same analytical values could not be interpreted in the same way. Perhaps the favorable correlations of plant tissue analyses obtained to date may have been fortuitous, and with more experience many exceptions may be found.

It was during an investigation of the fertilizer responses of grapes growing on soils previously found to be low in potassium by the replaceable base and Neubauer methods, that the opportunity arose to conduct plant tissue analyses and to compare them with soil tests. The results from this study will be reported in the data to follow.

CHEMICAL ANALYSES

Replaceable potassium determinations on soils were made by extracting them with normal ammonium acetate at pH 7.0. The Neubauer potassium values were determined by the technique outlined by Thornton (10). In each case the potassium was precipitated and weighed as potassium chloroplatinate. The potassium content of the finely ground leaf material was estimated after ashing, by the cobaltinitrite method (5).

PLOTS

Two series of plots were located on two different soil types with approximately the same potassium content (Table I). One series was established in northern California (in the Alexander Valley, near Healdsburg) on Corning gravelly loam and the other in southern California near Guasti on Tujunga sand.

The Alexander Valley plots were each composed of 40 Petite Sirah (*Rupestris* St. George root stock) vines (2 by 20) and separated from adjacent plots by a single guard row. Each treatment was replicated three times in a systematic manner so that a given treatment occurred but once in a block or tier.

At Guasti the plots of Mataro grapes on their own root stock consisted of two rows of 27 vines each and were separated from adjacent plots by two guard rows. Each treatment was replicated six times so that it occurred at random but once in a block.

The vineyards were not irrigated at either location, but were dependent upon the rainfall during the winter for an adequate supply of water.

FERTILIZER TREATMENTS

The fertilizers were placed on the bottom of plow furrows which were approximately 18 inches from the base of the vine. In order to minimize the fixation of phosphorus and potassium by the soil the fertilizers were placed on both sides of the vine in 2-inch ribbons of 12 to 18 inches in length. The materials were added in January to the Alexander Valley plots for the years 1935 through 1938 and at Guasti from 1939 through 1941. The rain which fell subsequent to the application of the fertilizer was believed to be sufficient to bring it into contact with the soil in part of the root zone. The treatments applied at the two locations are given in Tables II and III, which follow in the text.

SAMPLING OF LEAVES

Grape leaf samples were collected periodically up to the time of harvest when the last collection was made. The most recently "matured" leaf starting from the tip of the cane (shoot) was taken for the sample. The leaves were separated at the time of picking into petioles and blades, which were dried later at 80 degrees C and then ground in a Wiley mill to pass the 40-mesh sieve. Two leaves were taken from the opposite sides of each vine at Guasti, while four leaves were taken from each vine in the plots at Alexander Valley. The petioles and blades from each plot were analysed separately and the data from each location was tabulated and treated statistically (3, 8).

RESULTS

Soil Analyses:—The replaceable and Neubauer potassium values of the soil samples taken from the untreated plots at both locations are tabulated in Table I. These values differ considerably between the two locations and within each location, but nevertheless, they have

TABLE I—REPLACEABLE AND NEUBAUER POTASSIUM OF SOILS FROM UNTREATED PLOTS AT GUASTI AND ALEXANDER VALLEY, CALIFORNIA

Plot Number	0 to 6 Inches*		6 to 24 Inches		24 to 42 Inches		42 to 60 Inches	
	Replace-able†	Neu-bauer†	Replace-able	Neu-bauer	Replace-able	Neu-bauer	Replace-able	Neu-bauer
<i>Plots at Guasti</i>								
7	104	100	99	103	67	197	34	65
15	76	67	147	123	76	122	45	96
26	96	0	56	94	63	66	35	54
37	133	69	133	129	72	62	69	25
44	125	244	163	269	133	178	119	228
60	119	98	141	100	83	111	80	7
Average	109	96	123*	136	82	123	64	79
<i>Plots at Alexander Valley</i>								
1	65	105	65	144	94	110		
7	71	76	62	75	105	102		
13	154	92	131	76	117	127		
19	94	77	80	84	74	78		
Average	96	88	85	95	98	104		

*Soil depth.

†Given as parts per million of potassium in air dry soil. The Neubauer and replaceable potassiums were determined by Dr. O. Lilleland and Mr. J. G. Brown.

practical significance. Since the vines at Alexander Valley have responded to potassium applications, the potassium values from the untreated plots may be used as reference points. If this is done, then soils at other locations with similar replaceable or Neubauer potassium values (*e.g.* 100 parts per million or less), should likewise respond to potassium applications. The soils from the untreated plots at Guasti, except from plot 44, have potassium values either approximately equal to or less than those at Alexander Valley, and accordingly, one should expect to find a similar potassium response. This was not the case

as will be shown later.

Comparison of Petiole and Blade Analyses:—

The potassium contents of the leaf blades taken from the Alexander Valley plots are given in Table II and in Fig. 1 for the years 1939, 1940, and 1941. The addition of potassium from 1935 through 1938 resulted in a small but significant increase in the potassium content of the blades in the spring. As the season progressed these differences became smaller until at harvest time, during some years, there were no significant differences between them.

The leaf petioles (Table II and Fig. 2) taken at the same time as the blades are much higher in potassium than the corresponding blades (Table II and Fig. 1). The differences between the potassium and no potassium treatments are likewise much greater for the petioles than for the blades. These differences became greater during the summer and then decreased at harvest time. The potassium percentages of the petioles from the plots without potassium reached very low levels by mid-summer. The leaves from these plots during the last two pickings were frequently accompanied by marginal scorching of the leaf blades, a symptom characteristic of potassium deficiency.

Comparison of Petiole Analyses to Yields at Alexander Valley:—

Although the potassium content of the leaf petioles from the vines receiving potassium was higher than those without added potassium, the yields were not always increased (Table II). This was true in 1939 when the rainfall (fourth lowest during a 64-year period) was evidently inadequate for the plants to utilize the additional potassium. During 1940 and 1941 the rainfall was much higher and the yields were

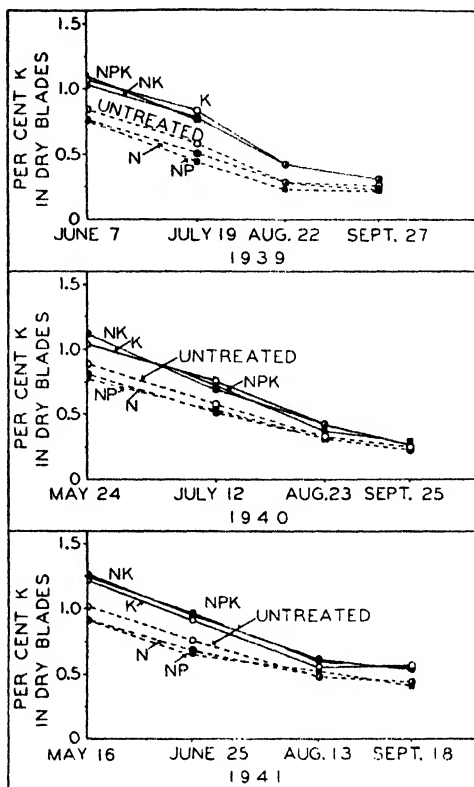


FIG. 1. The potassium content of blades of the first "mature" apical leaves taken from the fertilizer plots of Petite Sirah grapes in the Alexander Valley, Calif., for the 1939, 1940, and 1941 season. N = $\frac{1}{2}$ lb. of ammonium sulfate; P = $\frac{1}{2}$ lb. treble sulfate phosphate; K = 1 lb. potassium sulfate per vine applied each year from 1935 through 1938.

TABLE II.—POTASSIUM CONTENT OF LEAF PETIOLES AND BLADES CONTRASTED WITH YIELDS FROM PETITE SIRAH VINES ON CORNING GRAVELLY LOAM IN THE ALEXANDER VALLEY, CALIFORNIA

Treatments*	1939						1940						1941					
	K in Petioles (Per Cent)			Yields (Tons Per Acre)			K in Petioles (Per Cent)			Yields (Tons Per Acre)			K in Petioles (Per Cent)			Yields (Tons Per Acre)		
	Jun 7	Jul 19	Aug 22	Sep 27	Sep 28		May 24	Jul 12	Aug 23	Sep 25	Sep 24		May 16	Jun 25	Aug 13	Sep 18	Sep 22	
Untreated.....	0.84	0.58	0.28	0.26	2.33		0.89	0.58	0.33	0.25	3.10		1.02	0.76	0.48	0.44	2.92	
N.....	0.76	0.51	0.27	0.23	2.09		0.81	0.51	0.32	0.23	3.31		0.91	0.68	0.48	0.44	3.12	
NP.....	0.74	0.44	0.23	0.22	2.17		0.78	0.53	0.31	0.23	3.01		0.91	0.66	0.52	0.41	3.29	
K.....	1.07	0.83	0.42	0.31	2.50		1.04	0.76	0.42	0.32	3.87		1.22	0.91	0.55	0.57	3.98	
NK.....	1.03	0.78	0.42	0.31	2.32		1.12	0.69	0.42	0.26	3.76		1.27	0.95	0.61	0.54	3.66	
NPK.....	1.10	0.76	0.23	0.31	2.32		1.11	0.72	0.37	0.29	3.82		1.25	0.97	0.60	0.55	4.02	
Difference for significance.....	0.09	0.07	0.04	0.03	N.s.		0.22	0.11	0.03	0.04	0.65		0.14	0.10	N.s.	0.05	0.74	
Observed F val-ue†.....	32.2	60.0	47.8	30.0	1.36		4.74	8.13	31.0	5.89	3.06		13.8	21.0	2.34	21.0	3.77	
Rainfall (inches).....	—	—	—	—	19.6		—	—	—	—	56.8		—	—	—	—	73.6	

*Replicated three times; N = ½ pound ammonium sulfate; K = ½ pound potassium sulfate and P = ½ pound treble superphosphate per vine applied per year from 1935 through 1939.

†At the 5 per cent point (19 to 1 odds). N.s. = not significant.

‡Required F values at the 5 per cent point 3.33; 1 per cent point 5.64.

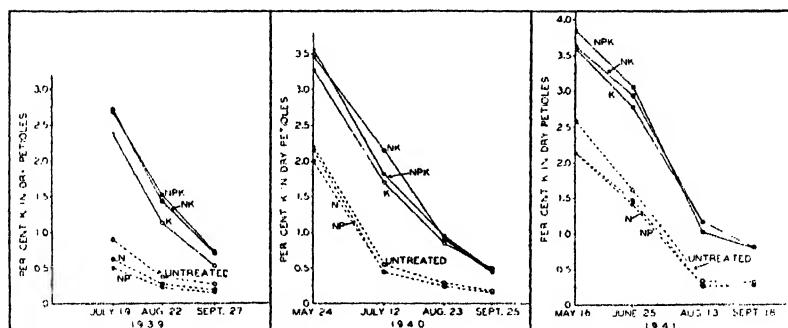


FIG. 2. The potassium content of petioles of the first "mature" apical leaves taken from the fertilizer plots of Petite Sirah grapes in the Alexander Valley, Calif., for the 1939, 1940, and 1941 seasons. N = $\frac{1}{2}$ lb. of ammonium sulfate; P = $\frac{1}{2}$ lb. treble sulfate phosphate; K = 1 lb. potassium sulfate per vine applied each year from 1935 through 1938.

directly related to the potassium present in the vines. The increases in yield for 1941 are statistically significant but in 1940 they just fail to be significant as shown by Snedecor's F test when all of the treatments are evaluated (Table II). When a statistical analysis is made

TABLE III—POTASSIUM CONTENT OF LEAF PETIOLES CONTRASTED WITH GRAPE YIELDS FROM MATARO VINE ON TUJUNGA SAND AT GUASTI, CALIFORNIA

Treatments*	1939		1940				1941			
	K in Petioles (Per Cent)	Yields (Tons Per Acre)	K in Petioles (Per Cent)			Yields (Tons Per Acre)	K in Petioles (Per Cent)			Yields (Tons Per Acre)
	July 8	September 24	May 14	July 10	September 3	September 27	May 28	July 11	September 20	September 21
Untreated . . .	1.60	2.26	1.70	1.45	0.45	2.54	2.73	1.49	0.37	2.83
P	1.57	2.09	1.69	1.34	0.42	2.46	2.53	1.41	0.37	2.59
K	1.71	2.04	1.84	1.44	0.46	2.75	2.80	1.56	0.47	2.57
PK	1.57	1.82	1.69	1.49	0.45	2.28	2.60	1.51	0.43	2.21
Grape pomace	1.85	2.45	1.96	1.45	0.48	2.78	2.84	1.59	0.44	3.15
N	1.65	2.48	2.11	1.51	0.40	3.68	3.24	1.67	0.44	3.89
NP	1.54	2.38	1.98	1.44	0.45	3.52	3.10	1.65	0.47	3.80
NK	1.58	2.14	2.03	1.53	0.49	3.36	3.09	1.75	0.54	3.57
NPK	1.81	2.51	2.08	1.57	0.53	3.32	3.03	1.80	0.54	3.72
X	1.65	2.16	2.08	1.37	0.47	2.96	2.83	1.64	0.43	3.33
Significant difference† . . .	N.s.	N.s.	0.18	N.s.	N.s.	0.62	0.78	0.17	0.09	0.75
Observed F value‡	2.01	0.71	6.68	1.49	0.67	4.88	5.76	3.97	3.45	5.13
Rainfall (inches)	—	17.4	—	—	—	15.8	—	—	—	32.7

*Replicated six times. N = 1 pound ammonium sulfate; P = $\frac{1}{2}$ pound treble superphosphate; K = 1 pound potassium sulfate; grape pomace = 35 pounds (containing 0.7 pounds of N); per vine each year from 1939 through 1941. X = 28.3 pounds of hog manure (0.57 pounds N) in 1939 and 1940.

†At the 5 per cent point. N.s. = not significant.

‡Required F value at 5 per cent point 2.10; 1 per cent point 2.83.

of the plots with and without potassium, regardless of N or P additions, then the added potassium resulted in a significant increase in yield (average yields with and without K were 3.82 and 3.19 tons per acre respectively). An F value of 16.70 was obtained for the statistical comparison of the two treatments, while an F value of only 8.53 was required for significance at the 1 per cent level.

It is to be noted that the increases in potassium of the leaf petioles and in the yield of the vines occurred even though the last fertilizer had been applied during January, 1938.

Comparison of Petiole Analyses to Yields at Guasti:—The addition of potassium to the vines at Guasti failed to increase significantly the potassium percentage of the leaf petioles during 1939 and 1940 (Table III). The increases in potassium which occurred on May 14, 1940 were directly related to the nitrogen application rather than to the addition of potassium. On the remaining dates in 1940 there was no significant effect of any of the fertilizer treatments on the potassium percentages. In 1941 nitrogen again caused the largest increase in potassium at the time of the first leaf sampling but the addition of potassium to nitrogen produced the largest increase in the potassium content of the petioles for the last two samplings.

The potassium present in the petioles at Guasti during the three year period was not related to the grape yields. The potassium percentages decreased with the season during each year but the rate of decrease was not as rapid as in the petioles from the Alexander Valley plots. Neither were the potassium values at harvest time from the untreated plots at Guasti nearly so low as those from the Alexander Valley plots. Evidently the vines at Guasti absorbed enough potassium from the low potassium soils to maintain an adequate supply under the conditions of growth prevailing during the experimental period. Further investigation revealed that the yields were limited by nitrogen rather than by potassium (12).

DISCUSSION OF RESULTS

A comparison of the soil analyses and the petiolar analyses indicates that the potassium content of the soil as determined by the replaceable and Neubauer methods failed to evaluate correctly the potassium status of the vines at the two locations. The potassium content of the petioles, on the other hand, reflected the potassium status of the vines satisfactorily. At Alexander Valley the potassium content of the petioles from the untreated vines reached a very low level in mid-summer when a considerable amount of growth was yet to be made. Comparable vines receiving potassium had a much higher potassium level during mid-summer and this was accompanied by higher yields during favorable years.

At Guasti during years of adequate rainfall the first factor limiting growth is nitrogen while potassium is potentially the second limiting factor. The addition of nitrogen promoted new root activity to such an extent as to supply potassium not only for the new top growth which took place but actually to increase the concentration of potassium within the plant. It was not until 1941 that the potassium added with the

nitrogen became effective in increasing the potassium present in the vines. However, with the continued addition of nitrogen alone to the vines, the increased growth will draw more rapidly upon the soil's potassium reserves than for the untreated vines unless potassium is added with nitrogen at the proper time to prevent a possible decrease in yield from a deficiency of potassium. An inadequate amount of moisture during any season would obviously minimize the effect of fertilizers unless the fertilized vines could withstand a drought better than those left untreated.

The time of occurrence of the minimum potassium values in the leaf petioles is of importance in relation to the yields. When the minimum potassium values appear just prior to harvest, as at Guasti, there is little opportunity for the potassium deficiency to influence the yields adversely. However, when the minimum levels occur in mid-summer as at Alexander Valley, then under favorable conditions of growth, the yields are depressed by a deficiency of potassium. Obviously the earlier this deficiency takes place the greater the probability of a decrease in yield from a lack of potassium, or for that matter, from any other nutrient or factor which may become limiting during the growing season.

The selection of the first "mature" leaf from the tip of the cane was adopted primarily because of the ease with which the samples could be taken and on the basis of theoretical considerations. The latter suggest that generally nutrients are translocated to the region of utilization and that whenever the supply of a nutrient is inadequate a deficit arises immediately. Since the "mature" leaf selected for analysis is adjacent to the growing point it would tend to reflect the changes in the nutrient status of the plant better than the older tissues which often lose their nutrients because of senescence. Through further study, however, other parts of the vine may be found more suitable to reflect the potassium, nitrogen or other nutrient status of grapes than the petioles of the "mature" leaves near the growing point.

The failure to correlate *soil* analyses with crop responses in this investigation may be caused by a difference in the ability of the two grape varieties to absorb potassium from the soil, or to a difference in their potassium requirements. These differences would then necessitate a different potassium level in the soil for each grape variety and possibly for each soil type. All these difficulties are overcome in evaluating the nutrient status of vines if the minimum potassium content of the *plant part* analysed is nearly the same for all varieties, soils, climates, and so on, which happens to be the case under the conditions of the present experiment.

SUMMARY

Fertilizer experiments with grapes were conducted on two soils with similar potassium content as shown by the replaceable and Neubauer methods. Leaf samples were taken periodically and analysed for potassium. The yields for three consecutive summers were directly related to the potassium content of the leaf petioles but not to soil analyses.

The potassium content of the leaf petioles reflected the potassium status of the vines better than the potassium content of the leaf blades.

The earlier the occurrence during the growing season of minimum potassium values in grape leaf petioles the greater the likelihood of a response from potassium application.

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Nitrate Content of Grape Leaf Petioles as an Indicator of the Nitrogen Status of the Plant¹

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DURING a study of the relationship of yields to the potassium content of grape leaf petioles from fertilizer experiments located on two soils with approximately the same potassium content, it was found at one location that the yields were related to the nitrogen rather than to the potassium applications (7). An investigation of the total, insoluble, soluble and nitrate nitrogen of the petioles and blades was undertaken to determine their suitability as indicators of the nitrogen status of grape vines. The results of this study will be reviewed in the present paper.

ANALYTICAL METHODS

Only the analytical methods used for the nitrogen determinations will be given, since the experimental technique employed has been outlined previously (7). Nitrates were determined photocolormetrically by the phenoldisulfonic acid method after decolorizing the water extract with a carbon black that neither adsorbed nor released nitrates. Calcium carbonate (5) was added to the aliquot for nitrate determinations in order to prevent nitrate losses from the extract and to minimize discolorization of the residue upon dehydration on the steam bath. Whenever the extracts could not be decolorized completely as in the leaf blades, the nitrates were estimated by the spot plate method with diphenylamine reagent.

Soluble nitrogen (non-protein nitrogen) was ascertained by extracting the ground plant material with 2.5 per cent trichloroacetic acid (3), while the insoluble (protein nitrogen) remained in the residue. The total nitrogen in the original plant material and in the extract was estimated by the Kjeldahl method after reducing the nitrates with iron (4). Since the sum of the soluble and insoluble nitrogen fractions agreed with the total nitrogen value when each was analysed separately, the insoluble nitrogen was determined subsequently by difference.

RESULTS

Nitrogen Analyses of Petioles and Blades:—The petioles and blades collected during 1940 from the untreated and nitrogen treated plots were analysed for nitrate, soluble, insoluble and total nitrogen (Tables I and II). Of these determinations the nitrate values of the blades (Table II) may be open to question, since the slightly colored extracts gave a reading with the photo-electric colorimeter even though the diphenylamine test for nitrates of the extracts were negative. Furthermore, if it is assumed that nitrates were determined satisfactorily in the blades by the phenoldisulfonic acid method, the differences for the

¹Conducted by the Division of Plant Nutrition and the Agricultural Extension Service of the University of California in cooperation with the Italian Vineyard Co. Assistance was furnished by the personnel of the Works Progress Administration Official Project No. 65-1-08-91-B-10.

TABLE I—NITROGEN ANALYSES OF LEAF PETIOLES FROM UNTREATED AND AMMONIUM SULFATE TREATED PLOTS FOR 1940

Plot Number	Treatment*	Per Cent Nitrate—N			Per Cent Soluble—N			Per Cent Insoluble—N			Per Cent Total—N		
		May 14	Jul 10	Sep 3	May 14	Jul 10	Sep 3	May 14	Jul 10	Sep 3	May 14	Jul 10	Sep 3
7.....	Untreated	0.0080	0.0015	0.0008	0.39	0.09	0.11	0.66	0.51	0.35	1.04	0.60	0.46
15.....	Untreated	0.0137	0.0012	0.0019	0.47	0.07	0.11	0.70	0.60	0.39	1.17	0.66	0.49
26.....	Untreated	0.0197	0.0027	0.0019	0.46	0.10	0.12	0.73	0.60	0.38	1.18	0.70	0.49
37.....	Untreated	0.0119	0.0015	0.0019	0.37	0.14	0.11	0.69	0.46	0.33	1.09	0.60	0.44
44.....	Untreated	0.0141	0.0012	0.0019	0.32	0.09	0.12	0.70	0.47	0.36	1.01	0.56	0.47
60.....	Untreated	0.0119	0.0015	0.0019	0.39	0.10	0.11	0.71	0.42	0.37	1.10	0.52	0.48
Average.....	—	0.0134	0.0016	0.0017	0.40	0.10	0.11	0.70	0.51	0.36	1.09	0.61	0.47
3.....	N	0.1759	0.0301	0.0302	0.86	0.19	0.15	0.76	0.58	0.46	1.62	0.77	0.61
18.....	N	0.1532	0.0246	0.0508	0.77	0.14	0.18	0.78	0.66	0.47	1.55	0.80	0.64
25.....	N	0.1310	0.0281	0.0205	0.71	0.17	0.17	0.81	0.67	0.46	1.51	0.84	0.63
38.....	N	0.1542	0.0254	0.0155	0.68	0.21	0.19	0.78	0.45	0.43	1.46	0.66	0.61
43.....	N	0.0985	0.0332	0.0438	0.61	0.16	0.18	0.77	0.53	0.42	1.38	0.69	0.60
57.....	N	0.1104	0.0367	0.0395	0.66	0.16	0.19	0.75	0.59	0.42	1.41	0.75	0.61
Average.....	—	0.1372	0.0296	0.0334	0.71	0.17	0.18	0.78	0.58	0.44	1.49	0.75	0.62
Observed F value†	—	105.5	215.1	31.8	54.1	26.8	120.0	35.4	2.37	38.4	72.0	14.0	210.0

*N = 1 pound ammonium sulfate per vine applied each year during January 1939, 1940 and 1941.

†Required F value at the 5 per cent point 4.96; 1 per cent point 10.04.

TABLE II—NITROGEN ANALYSES OF LEAF BLADES FROM UNTREATED AND AMMONIUM SULFATE TREATED PLOTS FOR 1940

Plot Number	Treat-ment*	Per Cent Nitrate—N			Per Cent Soluble—N			Per Cent Insoluble—N			Per Cent Total—N		
		May 14	Jul 10	Sep 3	May 14	Jul 10	Sep 3	May 14	Jul 10	Sep 3	May 14	Jul 10	Sep 3
7.....	Untreated	0.0062	0.0015	0.0032	0.67	0.56	0.28	2.87	2.34	1.87	3.54	2.90	2.15
15.....	Untreated	0.0065	0.0023	0.0016	0.67	0.42	0.31	2.90	2.48	1.92	3.57	2.90	2.23
26.....	Untreated	0.0081	0.0027	0.0024	0.74	0.58	0.49	2.74	2.47	1.85	3.48	3.03	2.34
37.....	Untreated	0.0077	0.0023	0.0032	0.64	0.49	0.48	2.80	2.14	1.65	3.56	2.62	2.13
44.....	Untreated	0.0031	0.0015	0.0012	0.52	0.55	0.34	2.71	2.23	1.66	3.23	2.77	2.00
60.....	Untreated	0.0081	0.0012	0.0028	0.70	0.50	0.61	2.82	2.11	1.77	3.51	2.61	2.38
Average.....	—	0.0070	0.0019	0.0024	0.66	0.52	0.42	2.81	2.30	1.79	3.48	2.81	2.21
3.....	N	0.0081	0.0012	0.0020	0.91	0.51	0.58	3.14	2.66	2.06	4.04	3.17	2.64
18.....	N	0.0088	0.0008	0.0032	0.97	0.45	0.45	3.07	2.78	2.11	4.04	3.23	2.56
25.....	N	0.0050	0.0008	0.0020	0.93	0.68	0.41	3.08	2.64	2.08	4.01	3.32	2.49
38.....	N	0.0081	0.0012	0.0032	0.81	0.62	0.50	3.22	2.33	1.81	4.03	2.95	2.31
43.....	N	0.0077	0.0027	0.0028	0.77	0.66	0.54	3.01	2.35	1.95	3.78	3.01	2.49
57.....	N	0.0058	0.0008	0.0020	0.81	0.53	0.55	2.99	2.44	1.95	3.80	2.97	2.50
Average.....	—	0.0072	0.0013	0.0025	0.87	0.58	0.51	3.09	2.53	1.99	3.95	3.11	2.49
Observed F value†	—	0.08	2.98	0.11	21.7	1.70	2.17	37.9	5.66	10.1	41.4	10.0	16.1

*N = 1 pound ammonium sulfate per vine applied each year during January 1939, 1940 and 1941.

†Required F value at the 5 per cent point 4.96; 1 per cent point 10.04.

two treatments are not significant and therefore these values cannot be used to estimate the nitrogen status of grape vines.

A statistical analysis (6) of the remaining nitrogen fractions indicates that significant differences for the petioles from the untreated and nitrogen treated plots were obtained on each sampling date for the nitrate, soluble and total nitrogen determinations (Table I) while for the insoluble nitrogen determinations significant differences were obtained on May 14 and September 3 but not for July 10. For the blades (Table II) only the insoluble and total nitrogen determinations were significantly different while none of the nitrate values and only the soluble nitrogen values for July 10 were significantly different. Of the nitrogen determinations which were significant only the nitrate content of the petioles appears to be of practical importance. The differences in the nitrate values for the two treatments are of the order of tenfold as compared to not more than doubled for the other nitrogen determinations.

Comparison of the Nitrate Content of Leaf Petioles to Yields and Sugar Percentages:—The average nitrate content of the petioles expressed in parts per million are given in Table III for each collection date. These values are contrasted with yields and sugar percentages of the years 1939 through 1941. Only one set of leaves was taken during 1939 and the petioles of these when taken from the nitrogen treated plots (except hog manure) had small but significant increases in their nitrate content. The slightly higher nitrate level of these plots had no significant effect on the yields in 1939. The small increases in

TABLE III—NITRATE CONTENT OF MATARO GRAPE LEAF PETIOLES CONTRASTED WITH SUGAR PERCENTAGES AND YIELDS FROM VINES ON TUJUNGA SAND AT GUASTI, CALIFORNIA

Treatments*	1939			1940						1941				
	Ppm Nitrate (Jul 8)	Yields\$	Per Cent Sugar||	Ppm Nitrate in Petioles			Yields\$	Per Cent Sugar||	Ppm Nitrate in Petioles			Yields\$	Per Cent Sugar||	
				May 14	Jul 10	Sep 3			May 28	Jul 11	Sep 20			
Untreated	153	2.19	25.1	593	71	77	2.54	24.8	163	138	62	2.83	22.4	
P	144	2.03	24.7	500	68	68	2.46	25.3	167	138	80	2.59	22.8	
K	129	1.98	24.4	318	32	0	2.75	24.8	100	100	49	2.57	23.0	
PK	150	1.76	24.5	308	18	5	2.28	24.9	133	146	51	2.21	22.7	
Grape Pomace . .	156	2.37	24.4	950	93	83	2.78	25.3	200	175	57	3.15	23.0	
N	217	2.40	25.3	2430	1300	1475	3.68	25.2	2879	1858	1731	3.89	23.6	
NP	185	2.31	25.0	5080	950	1305	3.52	25.3	2813	1867	1323	3.80	23.3	
NK	258	2.07	25.5	3140	750	1395	3.36	25.5	2071	2175	1923	3.57	23.5	
NPK	223	2.44	25.0	3680	843	926	3.32	25.6	2358	2013	1765	3.72	23.5	
X	147	2.10	24.9	4510	658	1020	2.96	25.4	629	308	124	3.33	23.3	
Significant difference†	61	n.s.	0.7	715	212	374	0.62	n.s.	420	334	457	0.75	0.54	
Observed F value‡	4.06	0.71	2.10	54.5	40.8	23.9	4.88	0.99	68.1	64.5	27.8	5.13	4.35	

*Replicated six times. N = 1 pound ammonium sulfate; P = $\frac{1}{2}$ pound treble superphosphate; K = 1 pound potassium sulfate; grape pomace = 35 pounds (0.7 pounds N) per vine applied each year from 1939 through 1941. X = 25.3 pounds of hog manure (0.57 pounds N) in 1939 and 1940.

[†]At the 5 per cent point (1). n.s. = not significant.

[‡]Required F value at 5 per cent point 2.10; 1 per cent point 2.83.

[§]In tons per acre; harvested September 24, 1939, September 27, 1940, and September 21, 1941; respectively.

^{||}Determined on the juice with a hydrometer calibrated in degrees Balling.

the sugar percentages caused by the treatments were significant as indicated by Snedecor's F test (6). Generally the higher sugar percentages were obtained for those plots which had received nitrogen.

During 1940 there were marked increases in the nitrate content of the grape leaf petioles taken from the plots which had received nitrogen (ammonium sulfate or hog manure). The nitrate level of the petioles from all nitrogen plots decreased during mid-summer and then at harvest time increased slightly. In contrast, the nitrate content of the petioles from the plots without added nitrogen decreased to a minimum level in mid-summer and then failed to increase at harvest time. The yields of all nitrogen treated plots excepting those receiving hog manure increased significantly over those without added nitrogen. The failure of the hog manure to increase the yields in 1940 may be associated with a slower availability of the nitrogen during the previous year as indicated by the lower nitrate values of the petioles on July 8, 1939. The sugar percentages of the juice in 1940 were not affected by the higher nitrogen level of the vines.

In 1941 the same general effect of nitrogen when applied as ammonium sulfate occurred as in 1940. The nitrate content of the petioles were higher and the yields were greater than from the plots without ammonium sulfate. The yields from the plots which had received hog manure in 1939 and 1940 became equal to those receiving ammonium sulfate but the nitrate content of the leaf petioles failed to equal those of the ammonium sulfate plots. This decrease in nitrate evidenced in the petioles may in the future influence the yields adversely unless the rate of nitrate formation at the time of leaf sampling during 1941 just happened to balance the rate of its utilization. The sugar percentages, as in 1939, were generally higher for the grapes receiving nitrogen (Table III), than for the corresponding ones without added nitrogen.

The addition of grape pomace to the vines for the three year period did not appreciably increase the grape yields or the nitrate content of the petioles. On May 14, 1940 the petioles of the pomace treated plots were higher in nitrate than those from the untreated plots but the nitrate concentrations were not nearly so high as in the petioles from the nitrogen treated plots. In 1941 the nitrate content of the petioles from the pomace plots at each sampling date did not differ significantly from those of the untreated plots. The nitrogen which may have been derived from the pomace was evidently utilized faster than it could be made available to the vines and this prevented an accumulation of nitrates in the leaf petioles. The amount of nitrogen obtained by the vines from pomace could not have been large, otherwise the yields would have been approximately the same as from the plots receiving ammonium sulfate or hog manure. Although the yields for the pomace plots are higher than for the untreated plots, the increases are not statistically significant, nor may they even forecast a trend since the pomace plots gave slightly higher yields prior to fertilization than the untreated plots.

DISCUSSION

Lagatu and Maume (2) in their analyses of grape leaves report nitrogen as total nitrogen (Kjeldahl method) in per cent of dry matter

of the leaf. Apparently, the nitrogen from the entire leaf was ascertained as no mention of petioles was made. Since the leaf blades constitute the bulk of the leaf, the total nitrogen values from the blades and not for the petioles would be comparable in the present experiments to those reported by Lagatu and Maume. If total nitrogen percentages are to be used to evaluate the nitrogen status of the vines, then this evaluation must be based on the small differences which occurred in the total nitrogen content of the blades obtained from the two treatments (Table II). On May 14 there is an average difference of 14 per cent for the two treatments; on July 10, 11 per cent; and on September 3, 13 per cent. All these differences are highly significant statistically but their small magnitude would make it somewhat difficult to assess their relationship to the nitrogen status of the vines. In contrast to these relatively small changes, the differences in the nitrate content of the petioles (Table I) are very much greater. The increases in nitrate content of the petioles for the nitrogen treated plots over the petioles from the untreated plots (Table I) are 923 per cent for May 14, 1,750 per cent for July 10 and 1,965 per cent for September 3. Furthermore, the low nitrate values on July 10 and September 3 of the petioles from the untreated plots constitute under the present experimental conditions a deficiency of nitrogen. Nitrate values as low as these, as already mentioned for the blades, may be affected by the minute color of the residue of the extract after dehydration, and therefore the nitrate values are nearer to zero than as given.

SUMMARY

The nitrate content of grape leaf petioles from the most recently "matured" leaves of shoots or canes reflected the nitrogen status of vines as shown by yields better than the nitrate content of the leaf blades or the soluble, insoluble and total nitrogen content of the petioles or blades.

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Storage of Grape Pollen

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A NUMBER of investigators have demonstrated that the longevity of deciduous fruit pollens may be prolonged from 1 to 5 years or possibly more by regulation of the temperature and humidity during storage. Wanner (7) has discussed the earlier European work, previous to 1934, on the germinability of grape pollen as related to longevity. The important conclusions that concern us may be briefly summarized. Grape pollen germinates well as much as a week after collection under the usual laboratory conditions, but no germination has been demonstrated even 6 months later. An exceptional case reported by Lorbeer was a sample (1925) of *Rupestris du Lot* pollen stored over calcium chloride that gave 25 per cent germination after 13 months, but attempts to repeat this result during the next two years failed. Storage over concentrated sulfuric acid resulted in a very rapid loss in viability, the percentage germination decreasing over one-half in a few days. This loss in viability was associated with a decrease in pollen tube length in vitro. Wanner's recommendation to grape breeders is to employ only fresh pollen, in view of its rapid loss in germinability. In 1937 Nebel and Ruttle (5) reported successful storage of two grape pollens, the Concord and Golden Muscat, which retained their viability after being held for one year at 8 to 10 degrees C and 50 per cent humidity.

A considerable saving in time and effort might be effected if samples could be stored in a "pollen bank" and used as needed. The value of such a method becomes especially apparent if varieties blossom at different periods, if pollen must be obtained from another locality, or if the same variety is used frequently in hybridization. From the standpoint of the grape breeder the successful establishment of a pollen bank would require that the samples retain their viability for at least a year, preferably longer, and that normal seedlings would be obtained from the use of such pollen. It would be an added advantage if the same pollen sample could be used for more than a single season's work.

METHODS

Three varieties of *Vitis vinifera* L. were used: the Muscat of Alexandria, Thompson Seedless (Sultanina), and Monukka. Massed pollen samples were obtained June 2, 1938, from 20 clusters of each variety. The clusters were in one-half blossom stage and each was taken from a different vine. The pollen is easily gathered by striking the clusters upon a piece of plate glass. The pollen adheres to the surface and the extraneous flower parts are blown off. Using a razor blade, the pollen is then swept together on the glass surface and finally scraped over the projecting side of the plate into small shell vials or in druggist's gelatin capsules. This method of collection yields a uniform and clean pollen sample.

Four storage temperatures were used: -12 degrees C, 2 degrees C, 10 degrees C, and room temperature (20 degrees C). During the

course of the experiments fluctuations occurred for short time periods, the temperature ranges can be given as -11 to -12 degrees C, 0 to 2 degrees C, 9 to 14 degrees C, and 20 to 27 degrees C. Calculated relative humidities of 25 and 50 per cent were maintained with sulfuric acid-water mixtures, with the exception of -12 degrees C storage where the humidities maintained were approximately 28 per cent and 54 per cent.

Once each year during the pollination season (end of May) the sealed containers were taken from storage. They were left overnight in the laboratory to reach room temperature. The vials of pollen were then removed, taken to the field, and the samples used in pollinating, just as in routine breeding operations. As a test of the fertilization capacity of the pollen, pollinations were usually made on male sterile varieties as did Wanner (7), thus eliminating the need of emasculation or possibility of selfing of the female variety. Pollinations made in 1939 were on the variety Saint Emilion after emasculation, and these results must be considered less reliable owing to the effect of emasculation, age of flowers used, and possibility of some selfing. However, in 1940, 1941, and 1942 male sterile varieties were used. The technique was further refined by placing several of the pollens on portions of the same cluster, 50 to 200 flowers being pollinated with each sample. On the same afternoon, as soon as the pollens were brought back from the field, germination tests were made in 20 per cent sucrose solution, using the hanging drop method. This concentration was found to be optimum for grape pollen by Winkler (8). Three slides were cultured of each sample, 200 to 300 grains were counted on each slide. Only those grains that had tubes at least three times their diameter were considered as germinated. All results are given as the average per cent of germination after 6 hours at 25 to 26 degrees C.

DISCUSSION

The effect of the different storage treatments on the germinability of the pollen is presented in Table I. The most striking result is that all three varieties have shown the greatest longevity at a temperature well below freezing and at the lower humidity of 28 per cent. At the end of four years the Monukka sample has only decreased from 34 to 13 per cent, but the decline in the other two varieties is more marked. The most rapid fall in germinability is shown by the pollen having the highest initial germination, whereas Monukka with the greatest longevity to date had the lowest viability at the start of the experiment. This might indicate that pollens of a high initial reactivity are apt to decline more rapidly in viability. At 2 degrees C the lower humidity appears to add about a year to the longevity of the pollen when compared with 50 per cent humidity. Thus the germination percentage of the sample at 50 per cent humidity at the end of the first year is about that of the 25 per cent sample at the end of the second year. At the temperature of 10 degrees C the pollen remains viable for less than two years under the most favorable humidity. At room temperature, even with controlled humidity, the pollens do not survive a single year.

TABLE I—PER CENT POLLEN GERMINATION AFTER VARIOUS STORAGE TREATMENTS

Duration of Storage Period	Temperature and Humidity							
	-12*	-12	2	2	10	10	Room	Room
	28	54	25	50	25	50	25	50
<i>Thompson Seedless</i>								
Initial.....	44	44	44	44	44	44	44	44
1 year.....	35	26	6	8	14	<1	0	0
2 years.....	35	24	7	0	0	0	0	0
3 years.....	12	2	0	0	0	—	—	—
4 years.....	9	0	<1	0	—	—	—	—
<i>Muscat of Alexandria</i>								
Initial.....	57	57	57	57	57	57	57	57
1 year.....	29	21	16	12	8	<1	0	0
2 years.....	—	17	8	0	0	0	0	0
3 years.....	10	1	1	0	0	0	—	—
4 years.....	6	0	1	0	0	—	—	—
<i>Monukka</i>								
Initial.....	34	34	34	34	34	34	34	34
1 year.....	35	31	19	8	8	0	0	<1
2 years.....	23	26	6	0	0	—	—	—
3 years.....	—	3	0	<1	0	—	—	—
4 years.....	21	0	<1	0	0	—	—	—

*The upper number refers to temperature of storage in degrees C. and the lower to the per cent relative humidity.

The results above do not agree entirely with the optimum temperature and humidity conditions that have been reported for deciduous fruit pollens. Nebel (4, 5) has stated the optimum conditions for a number of pollens to be about 2 to 8 eight degrees C maintained in desiccators over sulfuric acid opened every 6 months with no control of the atmosphere and without light. Nebel, however, was judging from the results published by Holman and Brubaker (1), Pfundt (6), and Knowlton (3), and from the fact that he was able to hold pollen at the above-reported "optimum" conditions for a long period of time. Thus a sample of Montmorency cherry was showing 2 per cent germination after 5½ years. As Nebel (4) points out, the optimum humidity might be lower than 50 per cent. However, no temperatures lower than 2 degrees C were employed. King and Hesse (2), with as many as 16 pollens of deciduous fruit trees, gave the optimum conditions after 550 days to approximate 36 degrees F (2 degrees C) and 25 per cent relative humidity (the latter quoted by Nebel (4) as 28 per cent). Their experiments are not yet concluded.

They report storing pollen at 10 degrees F in one of the same storage-rooms that was used in the present experiment, but without any control of the humidity. The humidity control even at temperatures below freezing is very important. It is probable that longevity of fruit pollens—unless grape pollen acts in a far different manner—may be further prolonged by storage at temperatures below freezing and perhaps even at lower humidities than we have so far used for grape pollens. This is not an unreasonable supposition, since if pollens are not killed by low temperatures the rate of respiration would be kept lower and the pollen might be expected to have a longer life. In this

regard Knowlton (3) found that *Antirrhinum* pollen remains viable longest under conditions of low temperature (0 to -17° degrees C).

Some authors (1, 3) have indicated that even though pollen is able to germinate in vitro, fertilization and seed production may fail. Whenever possible the fertilization capacity of stored samples was checked with freshly gathered pollen of the same variety. The data are presented in Table II.

TABLE II—PER CENT SET OF SEEDED BERRIES OBTAINED WITH FRESH AND STORED POLLENS

Date of Pollination	Age of Pollen (Years)	Fresh	-12° 28	-12 54	2 25	2 50	10 25	10 50
<i>Sultanina</i>								
May 26, 1939.....	1	17	8	7	23	3	26	0
May 22, 1940.....	2	31	37	11	16	0	—	0
May 26, 1941.....	3	54	57	0	0	1	—	—
May 30, 1942.....	4	24	24	0	0	—	—	—
<i>Muscat of Alexandria</i>								
May 26, 1939.....	1	—	3	—	—	—	23	0
May 22, 1940.....	2	11	25	—	12	8	—	0
May 26, 1941.....	3	65	48	0	0	1	—	—
May 30, 1942.....	4	23	22	0	0	0	—	—
<i>Monukka</i>								
May 26, 1939.....	1	16	12	—	15	13	26	—
May 22, 1940.....	2	40	41	—	22	0	—	—
May 26, 1941.....	3	67	50	0	—	0	0	0
May 30, 1942.....	4	22	16	0	0	0	—	—

*The upper number is temperature in degrees C, the lower the per cent relative humidity.

The berries with seeds were harvested and the set expressed as a percentage of the number of flowers pollinated. These results must be compared with the normal sets obtained with the use of fresh pollen on the same variety for the year in question. One can then compare the pollen germination in vitro as given in Table I with the fertilization capacity of the same sample. In only a single instance has a pollen sample that was considered wholly inviable by germination test resulted in a fertilization; this was a sample of Thompson Seedless stored at 2/50 and used after 3 years. Even here the berry set was only 2 per cent of the set obtained with fresh pollen.

When pollens showing germinations in vitro of 1 to 3 per cent are used in pollination they practically always fail to bring about fertilization. However, pollens producing as few as 6 to 8 per cent of viable grains in culture may produce sets that approach or occasionally exceed the normal sets. Thus the sample of Thompson Seedless 2/25, which after 2 years showed 6 per cent germination produced a set 135 per cent of normal, and the sample of Monukka 10/25 after 1 year in storage produced a set of 162 per cent of normal. By further comparisons of germinability in vitro and fertilization capacity it is obvious that there is practically no correlation between berry set and the relative germinability of pollen, providing the pollen gives more than 4 or 5 per cent germination. Expressed in another way: a pollen sample with a high average germinability might be no more successful

in accomplishing fertilization than a pollen sample of medium or low viability. These conclusions would agree with the experiments performed by Wanner (7) who failed to demonstrate that high yields of individual vines were associated with high viability of the pollen.

For practical purposes the grape breeder in making routine crosses should hardly rely on pollen samples of less than 6 per cent germination. It would appear, therefore, (Table I) that under the best storage conditions reported herein it would be risky to expect a pollen sample to remain useful for much more than 4 years.

Under the best storage conditions of this experiment, namely, -12 degrees C and approximately 28 per cent relative humidity, the pollens have retained sufficient viability to enable them to be used just as well as fresh pollens. Thus the percentage berry sets of 4-year-old pollen are practically normal. Seedlings grown from using 3-year-old pollen thus far appear equal in growth and as normal as those arising from pollinations with fresh pollen. It will of course be necessary to bring progenies to fruiting before one can be certain that no genetic changes of consequence have been produced by the aging of such pollen samples.

SUMMARY

Pollen samples of three varieties of *Vitis vinifera* L. were stored under temperatures of -12, 2, 10, and 20 degrees C and confined in relative humidities of 25 and 50 per cent, with the exception of the -12 degrees C treatment held at relative humidities of 28 and 54 per cent.

Pollen longevity was increased most markedly at the lowest temperature, -12 degrees C; and the lowest humidity, 28 per cent. A sample of Monukka pollen with initial germination of 34 per cent showed 21 per cent viability after 4 years in storage.

It has been demonstrated that the fertilization capacity of a given pollen is practically nil if the pollen shows only 0 to 3 per cent germination in vitro. Pollens of 6 per cent or higher viability may give berry sets equivalent to normal. Pollens stored under the best conditions reported and used in pollinations each year gave berry sets equivalent to fresh pollen after 4 years.

The results reported indicate that the supposed optimum conditions of temperature and humidity for the storage of deciduous fruit pollens may be even lower than those so far reported.

It appears entirely feasible to establish a "pollen bank" in which the breeder may use samples each pollination season as needed, then returning them to storage for future use.

Seedlings grown from the use of 3-year-old pollen appear equal in growth and as normal as those hybrids produced with fresh pollen.

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Breeding New Tetraploid Grape Varieties

By H. P. OLMO, *University of California, Davis, Calif.*

THERE are now several grape varieties grown or introduced commercially which we have found to be tetraploid. The Muscat Cannon Hall was found to be the tetraploid Muscat of Alexandria (3). Undoubtedly further search for varieties that show enlarged or "giant" characteristics will add to this list (Table I). I am indebted to Mr.

TABLE I—TETRAPLOID GRAPE VARIETIES INTRODUCED OR GROWN COMMERCIALY*

Parent Variety (2X)	Tetraploid (4X)	Notes
Muscat of Alexandria	Muscat Cannon Hall	First described in England in 1835; grown only in European glasshouse trade.
Campbell	Early Giant	U. S. Plant Patent No. 42, November 8, 1932.
Campbell	Black King	Variety grown in Japan under this name.
Catawba	Otsubu Catawba	Variety grown in Japan under this name.
Concord	Wallis Giant	The same mutant known from California and Oregon.
Delaware	Benikawachi	Grown in Japan.
Koshu	Otsubu Koshu	Grown in Japan.
Niagara	Otsubu Niagara	Grown in Japan.

*Other tetraploid forms have recently been described (1, 6), but these have not been offered as having commercial possibilities.

Nagao Tsuchiya, Yamanashi-Ken, Japan, for furnishing cuttings of the Japanese varieties in 1938. Although not all of the varieties have been commercially proven, they have much larger berries and ripen earlier, in these respects being superior to the parent varieties from which they have arisen as spontaneous somatic mutants. However, of 20 tetraploid vinifera varieties observed for more than 4 years at Davis, the undesirable characteristics that may prevent commercial acceptance are: (a) Poor growth habit. The shoots have shorter internodes, resulting in too compact a vine. This results in sparse foliage cover of the fruit and is serious with varieties that sunburn, such as the tetraploid Flame Tokay and Muscat of Alexandria. The canes, shoots, and cluster stems are all very brittle, and there is considerable breakage of the vine from wind. The fruit requires more careful handling, and the keeping qualities are poor, as the cluster structure is more succulent and the berries are softer in texture. (b) Irregular and poorly set clusters. This is much more pronounced in some seasons than others, but most varieties set a smaller percentage of berries than the corresponding diploid (Table II). Some clusters may set compactly but others may remain straggly. (c) The total yield per vine is often less. Crop records on 15 vines of the tetraploid Thompson Seedless, averaged for the three years 1939 to 1941, showed 12.2 ± 0.8 (S.E.) pounds as compared to 21 ± 0.5 pounds for the diploid. This reduction in yield is in many tetraploids the result of fewer inflorescences per vine.

It has been found impossible to generalize for grape tetraploids as a whole. For example, the tetraploids derived from interspecific hybrids such as the Niagara, Catawba, and Delaware do not have such an undesirable growth habit as most of the vinifera tetraploids. The longer internode length present in these hybrids is shortened somewhat, but

TABLE II—PER CENT SEEDED BERRY SET OF SOME DIPLOID AND THEIR
CORRESPONDING TETRAPLOID VARIETIES WHEN SELF-POLLINATED
(SEASON OF 1941)

Variety	Species Derivation	Diploid (2X)		Tetraploid (4X)	
		Flowers	Per Cent Set	Flowers	Per cent Set
Campbell.....	Labrusca × vinifera	1004	38	1635	32
Catawba.....	Labrusca × vinifera	826	58	538	29
Delaware.....	Complex?	471	44	520	40
Niagara.....	Labrusca × vinifera	1229	54	772	50
Cornichon*.....	Vinifera	5665	17	4651	21
Folle blanche*.....	Vinifera	2507	65	1515	44
Muscat of Alexandria*.....	Vinifera	9166	5	9295	9
Zinfandel*.....	Vinifera	4282	58	5188	22

*Data from Randall, T. R. (5), seasons of 1939 to 1941.

the resultant growth habit is as good as many commercial vinifera diploids. In fruitfulness the same situation applies: the 4X Niagara, for example, has produced well-filled clusters at Davis, and even though the set is smaller than the diploid, the increase in berry size offsets this defect, whereas the Catawba and Koshu tetraploids have often given very irregularly set clusters. Among the vinifera wine grapes we also see such differences, the Carignane tetraploid produces well-filled clusters rather consistently, but the Zinfandel tetraploid is often very straggly.

We must conclude, therefore, that the results of tetraploidization in any given grape variety cannot be predicted with certainty. This indicates that it is not the mere doubling of the chromosome number per se that produces the typical features of a given tetraploid variety, but it is the changed genetic balance that does so. Thus the genotype of the particular variety in which doubling occurs plays a large role. In a number of 4X vinifera varieties studied by Randall (5), he has reached the same conclusion regarding their fertility relationships. Thus the 4X Muscat of Alexandria is actually more fertile than the diploid from which it arose, whereas other varieties may show quite the reverse.

It would appear, therefore, that some of the desirable features of tetraploidy can be maintained and the defects eliminated by breeding and selection, despite the fact that we are essentially dealing with autotetraploids in the grape, even in those derived from species hybrids. Certainly a most promising field is to increase the heterozygosity by the crossing of unrelated tetraploids.

Crosses were first made at this station between the varieties Muscat of Alexandria (4X) and Thompson Seedless (4X) in 1936. In this population three seedlings were grown to fruiting age, two were determined to be pentaploids and the other triploid. From these results and the more extensive data accumulated by Randall (5), the use of tetraploids in breeding can therefore be advantageous in further increasing the chromosome number. We have also produced numerous triploids, that appear to have promise as rootstock varieties because of their great vigor (4, 5). The pentaploids have desirable growth habit, but studies of their fertility are not yet completed. This same cross was

repeated on a larger scale in 1937, and from the population 10 tetraploids were obtained with the range in chromosome number determined as 76 ± 4 . These hybrids show markedly the effects of gene segregation, differing among themselves in growth habit and fertility despite the same approximate chromosome number. One tetraploid variety has the appearance of an extremely vigorous diploid, having produced canes measuring 20 feet in length in a single season, with leaves measuring 12 to 14 inches in width. The berry size of three seedlings is as large as the tetraploid parents, and in one even larger.

These preliminary results are mentioned only because the possibilities of breeding and selection among the tetraploid forms appears promising, with the possible outcome the production of varieties with much larger berries and with a vigor heretofore unknown amongst grapes. Large progenies now coming into bearing will allow us to present quantitative data of genetic interest.

SUMMARY

Some tetraploid grape varieties introduced or grown commercially are reported. These are creating interest because of their larger berry size and earlier ripening. Most tetraploid varieties have certain defects which prevent their commercial acceptability, among these is poor growth habit, irregular setting of fruit, and reduced yield. It is impossible to predict the effects of doubling the chromosome number of a given variety on its growth habit and fertility, and hence its possible commercial value.

The particular genotype of the original variety that undergoes duplication appears to determine the characteristics of the new tetraploid more than does the doubling of the chromosome number *per se*. Change in genotype brought about by crossing and selection amongst tetraploids will thus enable the breeder to produce new varieties having increased berry size, and other desirable features of the tetraploid condition and at the same time eliminate the defects such as reduced fertility and poor growth habit of the vine.

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Extending Guava Production to California

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THE common guava (*Psidium guajava* L.) is highly prized as a flavor fruit throughout the tropics of the world. The plant is injured by a few degrees of freezing and commonly has been thought to be slightly too tender for cultivation in California where only an occasional plant can be found. It has for many years been grown as a home fruit throughout the southern part of Florida, and in that state there are a few small commercial plantings. Owing to the penetrating aroma of some guavas, which to the uninitiated is sometimes obnoxious, the extension of guava cultivation in the United States has been very slow.

Although greatly liked by many as a fresh fruit the guava has seemed to possess no special qualities to justify its production otherwise than for local use. Recently, however, interest in the guava has been stimulated anew by the studies of Golberg and Levy (3) who reported that ripe and firm guava fruits contained the phenomenal quantity of 300 to 400 milligrams of ascorbic acid (vitamin C) per 100 grams of the fresh fruit, and that the blanched and dehydrated product ranged from 2,000 to 3,000 milligrams per 100 grams. One of the richest known natural sources of vitamin C is dried rose hips which according to Lund, Spur, and Fredericia (1) contained 2,000 milligrams of ascorbic acid to 100 grams, a rather lower quantity than that in the dried guava.

The guava, furthermore, is reported by Miller, Bazore, and Robbins (2) to be a good source of vitamins A and B and to contain some G. It thus seems clearly evident that an attractive highly flavored fruit so richly endowed with important vitamins, one at least in phenomenal quantity, is certain to demand greatly increased attention.

During the writer's early work in Florida from 1892 to 1897, he became greatly interested in guavas. In 1914 he was privileged to visit the Hawaiian Islands where again this interest was stimulated. Meanwhile, he had become associated with the University of California Citrus Experiment Station at Riverside, California, and not knowing that the guava was too tender to be grown successfully in California, he began to make a collection of Hawaiian types. Seedling progenies of these types were planted for trial in a warm hillside area on the Station property. Gradually seed of a number of selected types were secured from various sources, as Florida, Cuba, Mexico, Peru, Rhodesia, Transvaal, and Egypt, and small representative seedling progenies grown of each. These plants, several hundred in number, have many of them been in fruit since 1918 and all of the others since 1926.

FROST HAZARD

The Experiment Station, thus, has a background of over 25 years of experience in growing guavas at one place in California. During this period the young and tender leaves and tips of young twigs have been slightly scorched by frost about every third or fourth winter and twice the plants have been severely frozen back. Following one of these

severe freezes, that of January, 1937, the recovery of the plants was studied. The crop of 1936 had been harvested by the middle of January 1937 so that there was but little fruit remaining to be frozen. Considerable difference in cold resistance and in the rapidity of recovery was shown by different plants and also by the different groups, but all of the vigorous growing, best varieties threw up strong healthy sprouts from the base of the plants and these grew into large 5- to 6-foot long sprouts during the season. In quite a few plants of certain groups the old trunks, 3 to 5 inches in diameter, sprouted out at a height of 4 to 6 feet above the ground, and this at first seemed to indicate a better recovery. Later experience, however, indicated that better results would have been obtained if all of these old trunks had been cut back to the ground shortly or immediately after the freeze, as the new sprouts from the base in all cases produced a more vigorous and healthy growth.

In the spring and throughout the season of 1938 the growth was again vigorous and the plants flowered at the usual time in early summer and set a fair crop, but somewhat lighter than that of the 1936 season preceding the freeze. It is thus apparent that old bushes frozen to the ground in one winter, if followed by a moderately warm winter, lose only one complete crop. These plants have never been artificially heated as are the orange groves in the nearby valleys. By the use of such protection they doubtless could have been saved from injury.

The slight difference in hardiness exhibited by the different groups and individuals apparently is of considerable importance in the commonly occurring light freezes but is of minor importance in the occasional severe freezes. It should be stated, however, that a few progenies and plants are so tender that some are killed outright and fail to throw any or only very weak sprouts from the base. Such tender types should not be propagated for use in California.

ACREAGE AVAILABLE IN CALIFORNIA FOR GUAVA CULTURE

The Riverside section is not generally considered a particularly warm one for southern California but the fields in which these guavas were grown were in a warm location for the section. So far as it is possible to judge from temperature records and from the reaction of other crops such as lemons, limes, and avocados, there are thousands of acres of suitable lands in southern California on mesas and hillsides that would be just as well or better suited to guava culture than those where the plants are located at the Citrus Experiment Station. It is of interest to note in this connection that the guava thrives on almost any type of land, sterile and coarse to rich and loamy, from very dry to very wet. It is a "weed bush" in its habits. It responds gratifyingly to good conditions and good treatment but its range of adaptability is apparently greater than that of the other fruits grown in California, almost the only limiting hazard being cold.

THE PROBLEM OF PROPAGATION

The guava throughout the past has been propagated almost wholly by seeds and such varieties as have been named are usually unstable

racess. Good individuals have frequently been increased to a limited extent by using root sprouts and occasionally by grafting, but named horticultural varieties (clones) are practically non-existent. This is partially due to the difficulty experienced in propagation; budding and grafting are very difficult and stem cuttings usually fail completely. The most successful method of propagation now used is by root cuttings. Experience strongly indicates that plants of the guava, which are to be grown in sections where occasionally they are likely to be frozen to the ground, should be propagated by root cuttings so that the roots will be of the same variety as the top and thus not require regrafting or rebudding after a severe freeze.

THE USE OF NAMED VARIETIES

During the last two seasons 1940 and 1941, the writer has made a careful study of the seedlings of various progenies, that have been assembled and grown at the Citrus Experiment Station, and has presented the results for publication as a bulletin of the California Experiment Station.¹ Thirteen different groups and 32 varieties are named and described. The groups and varieties are sufficiently different one from another so that they may be identified by use of artificial botanical keys based on fruit characters only.

Naturally the range in variation is very great among these varieties based on seedlings grown from types assembled from various countries. In shape they range from oblate to spherical, obovate or long pyriform; in weight, as a variety average from approximately 50 to 200 or 300 grams, with extremes ranging from 15 to 700 grams or more; in surface color from light yellow to orange and green; in pericarp thickness from 5 to 20 or 25 millimeters; in flesh color from white to yellow, tan and red; in odor from very mild to very strong; in flavor from very acid to very sweet; in core size from very small to very large; in seed number from few to very numerous; and in mid-season of maturing from the middle of October to the middle of January. Among these 32 varieties are some that are apparently of outstanding value for general cultivation while others are named primarily because of their possession of certain characteristics that may render them valuable in breeding. As this was a pioneering attempt in distinguishing and naming guava varieties, a number are named that doubtless will finally be discarded.

The Riverside experiments have demonstrated time and again, that if one desires a certain character and known type of fruit, varieties possessing these characteristics must be propagated vegetatively. Commercial plantings of the guava should not be made of seedlings.

VITAMIN CONTENT OF FRESH GUAVA FRUITS

Since the discovery by Golberg and Levy (3) of the extreme richness in ascorbic acid of the guava, interest naturally centers on whether varieties vary in this character. Golberg and Levy worked with white-fleshed and red-fleshed guavas (varieties unknown and probably un-

¹The writer extends thanks to his colleague, Professor Wm. T. Horne who has assisted him greatly throughout this work.

named) and found the white fleshed fruits to give the highest ascorbic acid content. Only preliminary tests have been made of the Citrus Experiment Station varieties but these are very suggestive.

During December 1941 the expressed juices from the fruits of six different varieties were analyzed for the writer by Dr. Franklin M. Turrell of the Citrus Experiment Station and the results are reported in Table I. In making these tests, the juice, expressed under high pressure from the skin and outer pulp (the main edible portion), was used. While these estimates were made as milligrams of ascorbic acid per 100 cubic centimeters this is practically the equivalent of milligrams to 100 grams.

TABLE I—ASCORBIC ACID CONTENT OF GUAVA VARIETIES (FRESH FRUIT, PEEL AND PERICARP ONLY)

Guava Variety	Color of Flesh	No. Trees Sampled	No. Fruits Per Sample	Milligrams Ascorbic Acid Per 100 Cc	Juice pH
Riverside.....	White	1	22	432	3.75
Volusia.....	White	1	34	472	3.73
Hart.....	White	1	14	653	3.70
Webber.....	Red	1	33	104	3.78
Rolfs.....	Red	1	7	971	3.85
Longped.....	Orange	1	17	346	3.62

In discussing these analyses Dr. Turrell wrote as follows: "These values all seem well in line with those reported in literature. Golberg and Levy (3), report 300 to 450 milligrams of ascorbic acid for ripe and firm whole fruits per 100 grams. They found the skin, outer pulp, and inner pulp compared in ascorbic acid as 12:5:1. As we included no inner pulp, our values may be expected to be a little higher than theirs even though we used both ripe and firm, and overripe and soft fruit in a single sample. Golberg and Levy's values for overripe and soft fruit were 50 to 100 milligrams of ascorbic acid per 100 grams of fruit. This range seems to be very near the values found for the Webber variety which normally matures early and which was past maturity when our assays were made. Golberg and Levy say 'The use of soft fruit is attended by a sharp decrease in the vitamin content, values as low as 18 milligrams per 100 grams being found in some cases'. They also found that white fleshed fruits were usually richer in ascorbic acid than the red fleshed ones. Our results are in accord with this except in the case of the Rolfs."

It is interesting to note that most of the varieties that belong to the Detwiler group, namely, the Riverside, Volusia, Hart, and Rolfs, run high in ascorbic acid content. The Longped which also belongs to the Detwiler group ranks considerably lower but is still higher than the Webber which belongs to a very different group and gave the lowest content of the six varieties tested.

It is also of importance to note that the Rolfs, a pink fleshed variety, gave the highest content of ascorbic acid while the Webber, another pink fleshed variety, gave the lowest content among the six. It seems probable thus that the results reported by Golberg and Levy (3), where the pink-fleshed guavas gave lower records than the white-

fleshed fruits, were due merely to the chance that the pink fleshed fruits used by them were from types or varieties normally low in ascorbic acid content. This demonstrates again the necessity of naming varieties and using known sorts.

Tests of a frozen fruit puree made by D. G. Sorber of the United States Department of Agriculture from one of the Riverside guavas (No. 21-1-14) and kept frozen for 2½ years, gave 288 milligrams of ascorbic acid per 100 grams on a pure fresh fruit basis. The flavor of the frozen product was like the fresh guava.

TESTS OF DEHYDRATED GUAVAS

In cooperation with Dr. E. M. Mrak of the Division of Fruit Products, University of California, Berkeley, preliminary tests were made in the dehydration of certain varieties. The fruits used were all from the last of the crop of 1941, being picked and forwarded to Berkeley on January 20, 1942. Ripening thus out of season they probably could not be expected to give the maximum vitamin content of the varieties represented. In preparation for drying the fruits were quartered without peeling and the core (inner pulp and seeds) removed. The ascorbic acid content for the various varieties each treated by three different methods in drying are given in Table II.

TABLE II—ASCORBIC ACID CONTENT OF DEHYDRATED GUAVAS

Variety	Ascorbic Acid Content (Milligrams Per 100 Grams)			
	Treatment No. 1 Steam Blanched 2 Minutes, De- hydrated at 130 Degrees F	Treatment No. 2 Steam Blanched 2 Minutes, De- hydrated at 150 Degrees F	Treatment No. 3 Sulfured 20 Min- utes, Dehy- drated at 150 Degrees F	Average for Variety
Riverside tree No. 7-4-8.....	1780	1030	1890	1567
Detwiler seedling tree No. 7-4-7.....	1280	1480	1440	1400
Egyptian, several trees.....	1550	1200	1310	1353
Holguin tree No. 7-5-4.....	970	1220	1450	1213
Towns tree No. 7-5-3.....	920	570	600	697
Eloina tree No. 7-6-7.....	280	170	400	283
Average per treatment.....	1130	945	1182	

The data apparently indicated clearly, as in the preceding analyses, a marked variation in richness of vitamin C content in the different varieties tested. All of the three samples of each variety are mainly either fairly high in ascorbic acid content or fairly low. The extreme in richness of this set of six varieties is shown by the Riverside, while the Eloina is apparently a variety averaging much lower. The Detwiler seedling (No. 7-4-7) and the Egyptian are both fairly high, approaching the Riverside, while the Holguin and the Towns tend perhaps to be rather intermediate in richness. Another season's data might indicate different relationships.

From the data given, however, it seems evident that different varieties may be expected to vary greatly in their vitamin content and thus that it is highly important that the normal content of each variety be determined and high vitamin varieties selected for propagation.

COMMERCIAL PRODUCTS AND THEIR USES

The dehydrated product is crisp and light in weight and has a mild fruity flavor only slightly suggesting guava. Tests in the use of the dried guava as one uses dried apples, apricots, or pears have indicated that it is indeed an excellent dried fruit product. Stewed dried guava prepared by the writer and by several others cooperating with him has been pronounced by a number of testers an excellent highly flavored unique product. The writer believes that this dried product prepared and marketed in paper packages like breakfast foods would soon create a wide demand. Its advertising points, phenomenally rich vitamin content and fine unique flavor in a pure fruit product, are exceptionally appealing. So far as the writer is informed, these are the first cooking tests of dehydrated or dried guava ever reported.

The fresh fruit of the guava, like the apple, is used in all sorts of ways. Some varieties are excellent to eat out of hand or as desert fruits with sugar and cream, or in fruit salads. Canned or as jelly, marmalade, jam, or butter, the product, if correctly prepared, is unexcelled. In pies, cakes, and dumplings the fruit is unique. Guava juice is a fine product made either from the fresh fruit or the dried guava. Candies and confections, extensively used in the tropics, are wholesome and very attractive. It is the writer's belief that several of these products may be successfully commercialized in the United States.²

²Since the above article was prepared, a very important paper entitled "Vitamin C content of guavas" by W. W. Boyes and D. J. R. deVilliers has been published (*Farming in South Africa*, Vol. 17: pp. 319-336, May, 1942). The authors confirm the high concentration of Vitamin C in guavas generally, and the following quotation summarizes what perhaps may be considered as their most outstanding conclusion. "Very little Vitamin C is lost in the stewing of guavas. Concentrated guava extract lost its Vitamin C very rapidly but canned guavas proved to be remarkably stable under adverse conditions. Dried guavas and guava powders have been prepared; though rich in Vitamin C, the potency is rapidly lost in warm climates."

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Control of Poison Ivy (*Rhus Toxicodendron*) by Spraying¹

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METHODS of weed control by spraying have utilized various organic and inorganic chemicals. Sodium chlorate has been widely recommended as an herbicide. In March 1940 Martin E. and Harold Cupery (1) reported that ordinary poison ivy was found to be particularly sensitive to ammonium sulfamate spray treatments and that no appreciable new growth appeared after this material was applied.

Small quantities of ammonium sulfamate were furnished by the Grasselli Department of the E. I. DuPont de Nemours & Company and trials were started at the New Hampshire Agricultural Experiment Station in July 1940, to determine its effects in poison ivy control. Plots were selected along a stone wall on which vigorous ivy growth had reached a height of 4 or 5 feet. Individual plot borders were not established by measured area, but by the area within which 1- or 2-gallon applications of the spray material would fully cover the foliage. This was approximately 100 square feet per gallon. A commercial sodium chlorate compound was used for comparison. All materials were applied with a 3-gallon compressed air sprayer. In each treatment a surrounding area was left untreated for check purposes.

The objects of these tests were: (a) To test the herbicidal efficiency of ammonium sulfamate as a poison ivy (*Rhus Toxicodendron* L.) eradicator in comparison to sodium chlorate; (b) to determine the effect of the time of application at different periods during the growing season; and (c) to determine the effect of these chemical compounds on other vegetation covered in the process of spraying.

Sodium chlorate compound was used according to the manufacturer's recommendations, namely at the rate of 1½ pounds per gallon of spray. Ammonium sulfamate at a strength of ¾ pound per gallon was found to be relatively ineffective, hence in most of the trials ammonium sulfamate was increased to a strength of ¾ pound per gallon of solution. Table I shows the effects secured from these two materials when applied at various times throughout the year.

TABLE I—EFFICIENCY OF AMMONIUM SULFAMATE AND SODIUM CHLORATE
COMPOUND AS SHOWN IN PER CENT KILL FOR DIFFERENT PERIODS OF
APPLICATION TAKEN AT THE CLOSE OF THE NEXT GROWING SEASON

Material Used	Concentration	Per Cent Killing When Applied				
		Jul 6	Aug 5	Aug 26	Sep 18	Oct 5
Ammonium sulfamate	¾ pound to 1 gallon water	96.3	98.2	99.9	93.7	60.9
Sodium chlorate	1½ pounds to 1 gallon water	29.9*	0	—	0	4.7

*Sprayed again September 17, 1940.

¹Scientific Contribution No. 4 of the Biological Institute of the University of New Hampshire.

The immediate effect of sodium chlorate solution was to kill the poison ivy leaves. The ammonium sulfamate did not immediately affect the plant, but within 2 or 3 days the leaves began to turn brown and finally dried up. Since the readings, as indicated in the table, were made a year from the time of the last applications, they indicate the final effect of the spray rather than the immediate one. It will be noted from the table that sodium chlorate even when applied twice, once in July and again in September as a follow-up spray, gave a very poor kill. On the other hand ammonium sulfamate applied any time from the 6th of July up until September 18th, while the plants were still actively growing, resulted in complete kill of the plants. These counts were made on the basis of the number of green leaves which developed after the treatment. The October 5th spraying was so late in the year that many of the leaves were yellow and some had dropped from the plants, yet it gave a fairly high percentage of kill.

These treatments were continued during the early part of 1941, the first applications being made May 20 and others made at intervals thereafter. Even the May application apparently resulted in an almost perfect kill though these must be checked in 1942 to make certain that recovery does not occur. During the 1940 season at Durham, rainfall was well distributed with a heavy dew occurring almost every night. In 1941 the season was very dry with less than half the normal rainfall. From all appearances applications were equally effective both years. Plants other than poison ivy, covered with the ammonium sulfamate spray lost their leaves, but grasses recovered to some extent. The grass did not recover from chlorate. Young oak, wild cherry, sumac, and barberry plants growing among the poison ivy were killed when their leaves were covered with the ammonium sulfamate, yet if only the stems and trunks were sprayed no apparent damage resulted.

Since the woody stems of these other plants did not appear to be damaged, poison ivy was sprayed beneath and on the trunks of a few apple trees in 1940, resulting in the destruction of the poison ivy without apparent damage to the trees. In 1941 a larger number of trees were selected and treated in the same way, with practically complete control of the poison ivy and no apparent damage to the apple trunk. In a few cases where water sprout and sucker growth of apple were present and the leaves were sprayed. This sprout growth was killed. Upon examination it was found that there was a small brown area about $\frac{3}{4}$ inch in diameter in the bark and wood of the tree at the point where the sprout attached to the trunk. Care should be taken, therefore, in applying this material to apple trees that no apple leaves become covered and that water sprouts mingled with the poison ivy be removed before spraying.

Plants killed by this spray may still retain their toxic properties for some time as evidenced by severe ivy poisoning to workers who removed dead plants 3 months after spraying.

Two years' trials indicate the following: Ammonium sulfamate when applied in concentrations of $\frac{3}{4}$ pound per gallon of water is an effective killing agent for poison ivy. The applications may be made any time during the active growth period of the plant. The soil is not so

severely sterilized as when sodium chlorate is used, and grass may recover. Applications to poison ivy on apple tree trunks will eradicate the ivy and not damage the trees if apple leaves are not sprayed.

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The Use of Metaphosphate in Nutrient Solutions

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IN a previous paper the author (1) presented data of a study on the effect of varying hydrogen-ion concentrations on growth of apple seedlings. One limitation of that investigation was that high pH values could not be studied with the buffer concentration employed because of the precipitation of certain of the constituents in the nutrient solution, notably calcium and iron.

In making a further study of the hydrogen-ion concentration it was desired to use higher pH values and also to devise some means by which iron could be maintained in solution at the higher values without the complication of adding it separately. The investigations of Hall and Schwarz (2) and others (3, 4) suggested the possibility of employing metaphosphate in nutrient solutions buffered at high pH to maintain iron and other constituents in solution. A few preliminary tests gave promising results and a solution culture experiment was set up using pH values up to 7.5.

MATERIALS AND METHODS

Ordinary quart Mason fruit jars were used as containers, painted on the outside to exclude light. Apple seedlings were germinated in sand and after attaining a height of about 5 centimeters, they were transplanted to the culture vessels. Four seedlings were used per jar, being supported on paraffined black paper. Sixty containers were prepared and placed in a large water bath, the temperature of which was maintained at 18 degrees C throughout the experiment. Continuous aeration of the nutrient solutions was provided by an air pump which forced air through a network of rubber tubing to which were attached sections of capillary tubing extending to the bottom of the jars.

The nutrient solution was a slightly modified Hoagland's, with a calcium nitrate concentration to 0.002 M. The concentration of buffer in the solutions was maintained at 0.005 M, varying the proportions of monobasic and dibasic potassium phosphate and phosphoric acid to obtain the pH values 4.0, 4.8, 5.8, 6.7, and 7.5. Iron tartrate was used as the source of iron.

In making up the solutions, the calcium nitrate, iron tartrate, magnesium sulfate and sodium metaphosphate stock solutions were added and diluted nearly to volume before the buffer and other nutrients were introduced. With this procedure the metaphosphate can exert its action on the calcium, magnesium and iron, converting them, to a certain extent, into soluble but unionized complexes as stated by Hall and Schwarz (2) before the buffer is added. With the addition of the buffer a high orthophosphate concentration is affected and, in the case of the high pH values, the hydrogen-ion concentration is markedly decreased; conditions which are favorable for the formation of insoluble salts of the elements concerned. Employing this technique no cloudiness or precipitation occurred when the solutions were prepared, nor did any develop during the 10-day to 2-week interval that the solutions were used before being renewed. On the other hand, in the solutions

containing no metaphosphate, appreciable precipitation occurred when the high pH solutions were prepared. Frequent pH determinations were made of the solutions but only slight changes were found to occur. As the seedlings grew larger it was found necessary to adjust the pH in some of the solutions occasionally to keep it within a fluctuation of 0.2 pH.

The seedlings were harvested on May 11, having grown 10 weeks in the solutions.

DISCUSSION

The data presented in Table I indicate that the growth of the seedlings was considerably restricted in the high pH cultures containing no metaphosphate and is less than at comparable pH levels in the solutions containing metaphosphate. The seedlings in the minus-metaphosphate cultures exhibited marked iron chlorosis at the high pH levels (see Fig. 1) in contrast with the normal green foliage which



FIG. 1. Top view of normal and chlorotic apple seedlings grown 10 weeks in nutrient solution maintained between 7.3 and 7.5 pH. The culture on the left contained sodium metaphosphate at a concentration of 0.10 per cent. Iron tartrate was added to both cultures in equal amounts.

developed on the seedlings throughout the pH range in the cultures containing metaphosphate. The data on iron in Table I are of interest in this connection.

Since such good results were obtained with metaphosphate in this study in preventing iron chlorosis when buffered nutrient solutions were used, it has been tried also in culture work with ordinary unbuffered nutrient solutions. The problem of iron availability is often encountered in nutrient solution work, especially where the solutions are used for extended periods without renewing. The hydrogen-ion concentration of the solution tends to decrease as the plants develop which favors precipitation of the iron. In nutrient solution work with apple plants it has been found that a solution of 5 milliliters of 1 M

TABLE I—THE EFFECT OF NUTRIENT SOLUTIONS AT VARIOUS PH LEVELS WITH AND WITHOUT SODIUM METAPHOSPHATE ON GROWTH AND IRON CONTENT OF APPLE SEEDLINGS

pH of Solution	Treatment		Average Dry Weight of Seedlings (Gms)	Fe in Dry Matter (Ppm)
	Fe Tartrate (Ppm)	Metaphosphate (Per Cent)		
4.0.....	---	---	1.21	100
4.8.....	---	---	1.52	111
5.8.....	50	0	1.18	98
6.7.....	---	---	0.73	97
7.5.....	---	---	0.33	90
4.0.....	---	---	1.67	125
4.8.....	---	---	1.56	120
5.8.....	50	0.10	1.47	130
6.7.....	---	---	1.35	127
7.5.....	---	---	1.37	120

sodium metaphosphate and 2.5 milliliters of 0.5 per cent iron tartrate per liter of nutrient solution gives splendid results in this connection. No orthophosphate is added in making up the solution, the metaphosphate being the only source of phosphorus. Apple plants apparently are able to utilize phosphorus in the meta-form as a number of leaf and stem tissue analyses have shown phosphorus to be as high in plants supplied with metaphosphate as in plants supplied with orthophosphate.

Iron tartrate is the only iron salt which has been tried extensively as yet. There is the possibility that other iron salts would give as good results or possibly even prove superior. More work is needed in this connection.

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Performance of Some Large-Seeded and Small-Seeded Peanut Varieties and Selections in Virginia and South Carolina¹

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COMMERCIAL production of large-seeded or Virginia-type peanuts in this country is confined mainly to an area embracing southeastern Virginia and northeastern North Carolina, with a lesser area in Tennessee. Small-seeded sorts such as Spanish, Valencia, Tennessee, and African are grown generally over the Southern States except in the area where large-seeded varieties are grown. For several years variety and strain tests and selection for varietal improvement have been conducted by the Bureau of Plant Industry in cooperation with the Virginia Agricultural Experiment Station at Holland, Virginia (2), and with the South Carolina Agricultural Experiment Station at Florence, South Carolina. Major attention has been devoted to the large-seeded type at Holland, and to the small-seeded type at Florence.

This report shows the comparative performance of: (a) seven of the most promising selections of the Virginia type along with the "Virginia Station" strain of Virginia Runner as a standard as well as a selection of Virginia Bunch designated as the Florence Strain; and (b) four of the best selections of Spanish along with good strains of Tennessee Red, Tennessee White, African, Valencia, and Spanish 18-38, which last is a standard strain of Spanish.

* METHODS

The 18 lots of both types of peanut were grown at Holland, Virginia, and Florence, South Carolina, in "modified latin squares" replicated six times, from 1937 through 1940. Single plots consisted of three rows 40 feet long and 33 inches apart with the plants a foot apart in the rows. Cultural and handling methods were typical of the respective localities, except that in 1940 all plots at Holland were dusted with sulphur for control of leaf spot diseases. At Holland the plots were on Onslow fine sandy loam and received 500 pounds per acre of 0-10-6 fertilizer annually. At Florence they were on Norfolk sandy loam in 1937 and 1938 and on Orangeburg sandy loam in 1939 and 1940, and received 500 pounds of 4-8-4 each year.

In the 1937-39 Holland tests individual-plant nut yields were determined for the center row in each plot in order to determine the magnitude of single plant variations within strains and seed-size groups.

For all years at Holland and 2 years at Florence, replicate shelling

¹Investigations conducted cooperatively by the Bureau of Plant Industry, the South Carolina Agricultural Experiment Station, and the Virginia Agricultural Experiment Station.

tests were made on 100-gram samples of pods as delivered by the picker, minus "trash". The data for yields and shelling percentages were analyzed by the variance method (3) treating them as if obtained from randomized blocks, although a small amount of bias was probably involved.

RESULTS

The results of the tests are summarized in Tables I and II. The 1940 data for Holland are presented separately because they are hardly comparable with those for the other years due to the modifying influence of the sulphur dust applied for leaf spot control.

Total Plant Weights:—Total plant weights are of interest because of the value of the tops as hay. It appears that at Florence (Table II) where no sulphur dust was applied the large-seeded type produced

TABLE I—SUMMARIZED RESULTS OF TESTS OF 18 LARGE- AND SMALL-SEEDED PEANUT VARIETIES AT HOLLAND, VIRGINIA, 1937-1940
(YIELDS ON ACRE BASIS)

Variety	Mean Yields of Cured Un-picked Vines 1940* (Pounds)	Mean Yields of Unshelled Nuts (Pounds)		Shelling Properties				Mean Calculated Yields of Shelled Nuts (Pounds)		
		1937-1939	1940*	Mean Shelling Percentages		Mean Number Shelled Nuts per Ounce		1937-1939	1940*	
				1939-1940	1937-1940	1939-1940	1937-1940			
A. Large-Seeded Varieties										
5-24 3	4662	1706	1676	71.3	70.2	34.0	33.2	1197	1179	
110872(8)	5203	1569	1914	71.1	70.0	32.7	33.1	1096	1343	
110751(4)	3945	1570	1346	70.4	62.9	32.5	32.8	1086	928	
110742	4642	1445	1584	67.7	66.8	25.3	27.4	964	1050	
110747(3)	5278	1603	1863	71.5	69.8	31.9	32.7	1119	1308	
Virginia Station (5)	4765	1668	1723	71.4	70.0	32.9	33.0	1162	1219	
110739(6)	5221	1486	1947	71.8	69.6	34.8	35.7	1023	1389	
110740(3)	5040	1440	1780	72.0	70.0	35.1	34.8	1003	1259	
Virginia Bunch (Florence Strain)	5828	1343	2226	75.0	73.4	51.2	52.4	989	1650	
Mean	4954	1537	1784	71.3	69.9	32.4†	32.8†	1070	1260	
Required for significance of difference between variety means at 5 per cent level	859	170	298	1.0	0.8	2.0	1.3	121	217	
B. Small-Seeded Varieties										
Valencia	5513	815	1230	72.1	71.8	72.2	69.4	585	881	
Spanish 18-38	5581	854	1362	78.0	78.1	104.6	100.1	671	1053	
Spanish 18-38-6-L-3	5680	956	1544	74.3	74.3	64.6	63.5	714	1127	
Improved Spanish 2-B	6134	987	1520	75.3	75.3	63.2	62.7	746	1136	
Improved Spanish X-C	6204	950	1575	73.7	74.1	66.1	64.4	710	1144	
Improved Spanish X-L-2	6015	970	1564	74.5	74.7	63.6	62.9	727	1144	
Tennessee Red	5218	779	1155	72.4	72.1	70.1	67.3	561	826	
Tennessee White	5546	933	1450	74.3	74.3	59.9	59.6	696	1059	
African	6378	976	1626	74.4	74.1	64.8	62.8	721	1206	
Mean	5808	913	1447	74.3	74.3	65.6†	64.1†	681	1063	
Required for significance of differences between variety means at 5 per cent level	†	123	230	0.9	0.6	2.3	1.2	93	187	

*All plots dusted with sulphur for leaf spot control.

†Differences not significant statistically.

‡Virginia Bunch (Florence Strain) and Spanish 18-38 not included in means shows since these numbers per ounce are obviously larger than those for other varieties in the respective groups.

TABLE II—SUMMARIZED RESULTS OF TESTS OF 18 LARGE- AND SMALL-SEEDED PEANUT VARIETIES GROWN AT FLORENCE, SOUTH CAROLINA, 1937-1940 (YIELDS ON ACRE BASIS)

Variety	Mean Yields of Cured Un-picked Vines, 1937-1940 (Pounds)	Mean Yields of Un-shelled Nuts (Pounds)		Shelling Properties		Mean Calculated Yield of Shelled Nuts 1939-1940 (Pounds)
		1937-1939	1937-1940	Mean Shelling Percentage 1939-1940	Mean Number Shelled Nuts Per Ounce 1939-1940	
<i>A. Large-Seeded Varieties</i>						
5-24-3.....	4565*	—	1467*	74.5	52.7	789
110872(8).....	4756	1907	1742	71.0	37.9	842
110751(4).....	4489	1717	1588	67.2	38.0	758
110742.....	3917	1650	1540	69.9	34.4	798
110747(3).....	4655	2032	1797	70.7	37.0	800
Virginia Station (5).....	4686	1760	1607	71.7	36.6	772
110739(6).....	4265	1680	1578	70.3	37.7	825
110740(3).....	4644	1854	1706	67.0	37.8	761
Virginia Bunch (Florence Strain)	4966	1927	1787	72.5	54.9	898
Mean.....	4547	1816	1668	70.6	37.0†	805
Required for significance of differences between variety means at the 5 per cent level..	380	176	133	1.2	1.0	†
<i>B. Small-Seeded Varieties</i>						
Valencia.....	2967	1438	1284	71.5	71.1	537
Spanish 18-38.....	3078	1521	1315	75.8	107.9	525
Spanish 18-38-6-L-3.....	3499	1649	1479	72.8	64.7	671
Improved Spanish 2-B.....	3006	1449	1346	73.0	64.3	711
Improved Spanish X-C.....	3175	1571	1406	74.6	63.3	648
Improved Spanish X-L-2.....	3313	1560	1344	74.0	65.1	540
Tennessee Red.....	2976	1460	1315	70.9	74.0	596
Tennessee White.....	3161	1525	1327	71.8	65.2	578
African.....	3368	1619	1444	73.0	67.0	635
Mean.....	3171	1532	1362	73.0	66.8†	604
Required for significance of differences between variety means at the 5 per cent level.....	216	105	89	0.7	2.6	105

*For 1938-1940 only—not included in type mean.

†Difference not statistically significant.

‡Virginia Bunch (Florence Strain), 5-24-3, and Spanish 18-38 not included in mean shown, since these are obviously larger numbers per ounce than those for other varieties in the respective groups.

significantly more forage than did the small-seeded kinds tested. Batten and Poos (1) and Miller (4) have shown that low yield of tops on non-dusted small-seeded varieties is due largely to premature defoliation by leaf-spot diseases. Unfortunately, data on total plant weights were not obtained on non-dusted plants at Holland. The 1940 results at Holland (Table I) show that the small-seeded type produced more forage than the large-seeded group when both were dusted.

At Holland, 110751(4) was a shy yielder of forage while Virginia Bunch (Florence Strain) was outstandingly high in the large-seeded group. Within the small-seeded group there were no significant differences. At Florence the 110742 strain of the large-seeded type produced less hay than the standard, while none significantly exceeded the standard. Of the small-seeded types Spanish 18-38-6-L-3, Improved Spanish X-L-2, and African were significantly better than the Spanish 18-38, and the others about the same as Spanish 18-38.

Yields of Unshelled Nuts:—Of the large-seeded strains at Holland none was significantly superior to the Virginia Station (5) standard strain during 1937–1939, although the Virginia Bunch (Florence Strain) outyielded it in 1940 when all varieties were dusted. The latter, however, has much the smaller kernels and is hardly typical of the group in this respect. At Florence, 110747 (3) outyielded the Virginia Station (5) standard, and the Virginia Bunch (Florence Strain) approached significant superiority in yield but it must be borne in mind that its kernels were nearly as small as those in the small-seeded group.

When the small-seeded group at Holland was dusted in 1940 the yields were much closer to the large-seeded group than in previous years. Within this group the several Spanish selections closely approached significant superiority over Spanish 18–38 in 1937 to 1939 but showed less significant superiority in 1940 when all were dusted. African also appeared probably superior in yield. At Florence for the 4-year period Spanish 18–38–6–L–3, Improved Spanish X–C, and African yielded better than Spanish 18–38. The others were not significantly different from Spanish 18–38.

Comparisons between groups are also of interest. When not dusted, the large strains at Holland yielded about 50 per cent more than the small ones, but when dusted one season the superiority was only about 20 per cent. At Florence (no sulphur) the yields of unshelled nuts of the large type were about 300 pounds (about 20 per cent) more than of the small type. Part of this apparent superiority is lost because of the lower shelling percentage of the large type, but these data indicate that still they outyield the small type under Florence conditions.

An analysis of the single-plant variation within strains at Holland for 3 years showed no significant difference in variability that could be associated with seed-size group. The average coefficients of variability were 40.4 per cent for large-seeded and 39.6 for small-seeded strains. Tennessee Red was notably highly variable, and it was also one of the lowest yielding varieties.

Shelling Properties:—At Holland, 110742 appeared to be the only large-seeded sort that was definitely inferior to Virginia Station (5) in shelling percentage, and Virginia Bunch (Florence Strain) the only one with a significantly higher percentage. The small seed size of the latter, however, places it rather between the truly large-seeded and small-seeded groups. Despite the low shelling percentage of 110742 it had the largest seeds in the group at both locations. Of the small-seeded groups, Spanish 18–38 had by far the best shelling percentage and smallest seeds (100.1 per ounce), while Valencia and Tennessee Red were definitely inferior in shelling percentage. These latter two were also poor yielders. With the exception of Spanish 18–38 the other seed sizes were roughly similar, running from 60 to 70 per ounce.

Two years' data at Florence show only one large-seeded strain to have a significantly better shelling percentage than Virginia Station (5), namely, 5–24–3, a selection that produced very small seeds for a Virginia type (52.7 per ounce). Two rather low yielding large-seeded strains produced significantly lower shelling percentages than the

standard strain. As at Holland, Spanish 18-38 had the highest shelling percentage in the small-seeded group (75.8 per cent) and all others were significantly lower. This strain had much the smallest seeds (107.9 per ounce) with the others ranging mainly from 65 to 70 seeds per ounce.

A typical tendency toward higher shelling percentage in the smaller-seeded group is evident throughout this work. Shelling percentages of the small-seeded group averaged about 1 per cent higher at Holland than at Florence. Counts of seed per ounce were about five more for the large type at Florence than at Holland, and one more for the small type.

Yields of Shelled Nuts:—Generally, the yield per acre of shelled nuts is the best index of a variety's productivity. Calculated yields of shelled nuts in the last columns of Tables I and II permit comparisons within locations but are hardly comparable between locations. By this criterion alone, no large-seeded strain outyielded Virginia Station (5) significantly at either location, when no sulphur was applied. In 1940, however, the Florence Strain of Virginia Bunch appeared superior in yield. The small seed size of this strain should be kept in mind.

Of the small-seeded types at Holland, none were definitely superior to Spanish 18-38 in yield of shelled nuts per acre, but at Florence, Spanish 18-38-6-L-3, Improved Spanish 2B, Improved Spanish X-C, and African were significantly superior. None were very definitely lower than Spanish 18-38 at either location.

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A Rapid Method for Estimating Carbon Contained in Plant Tissue Extracts¹

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IN NUTRITION studies on plant extracts it is important to know the amounts of carbohydrates in relation to the nutrients in the extract. The fruiting tendencies of a plant and the concentration of nutrients contained in its extracts are influenced by carbohydrate supplies. The methods for determining reducing sugars and other carbohydrates give a measure of these supplies, but these methods are long and require considerable apparatus and careful technique. This paper presents a rapid method for estimating the carbon contained in carbohydrates and proteins or amino acids in a plant extract and the results of numerous tests show the results to be highly correlated with the nitrogen present, and yields.

Previous papers (2, 3) have shown that concentrated sulfuric acid acts on carbohydrates and proteins to produce a brown solution which may be measured in a colorimeter. The color concentration seems to follow Beer's law quite well although there is a slight constant deviation.

Previous procedures required heating with a uniform heat until fumes of sulfur trioxide came off. The difficulty in this technique, besides being rather long, is that if the heating is not done exactly right, some of the carbon will be oxidized. This proved to be especially true when preparing the standard, and results tended to be high if the standard was weakened by oxidation of small amounts of carbon. However, if the heating is carried out under certain conditions, both with the standard and unknown, quite accurate results may be obtained provided the concentration of the unknown is quite close to that of the standard.

In working with plant extracts it was found that this difficulty of unequal heating could be practically overcome by treating the extract with fuming sulfuric acid. When this was used, enough heat was developed to produce the brown color and the action was so rapid and uniform that little variation due to oxidation was detected, or if it was present it was constant, as shown by the constant difference between readings of carbon from various concentrations of sugars.

Of course, there may be small amounts of carbon in the form of alkaloids, organic acids, and so on, which are not carbonized, but it is quite certain that all carbohydrates are determined, since the action of sulfuric acid is specific for withdrawal of water from them. Previous work (2) shows that the carbon in amino acids and proteins is also determined.

PROCEDURE

Reagents:—(a), .03125 per cent sucrose solution; this contains .01316 milligrams of C per cubic centimeter; (b), fuming sulfuric acid

¹The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

TABLE I—COMPARISON OF DETERMINATION OF GLUCOSE AND SUCROSE BY PHOTOELECTRIC COLORIMETER

Date	Glucose (0.0125 Mg C Per Cc)			Sucrose (0.01316 Mg C Per Cc)			Glucose (0.00625 Mg C Per Cc)			Sucrose (0.00658 Mg. C Per Cc)			Glucose (0.003125 Mg C Per Cc)			Sucrose (0.00329 Mg C Per Cc)		
	Reading	Deviation From Mean (Per Cent)		Reading	Deviation From Mean (Per Cent)		Reading	Deviation From Mean (Per Cent)		Reading	Deviation From Mean (Per Cent)		Reading	Deviation From Mean (Per Cent)		Reading	Deviation From Mean (Per Cent)	
Oct 8.....	90.0	±1.56		94.0	±1.67		43.0	±3.30		45.5	±4.00		19.5	±2.23		19.5	±2.74	
Oct 15.....	93.5	±2.27		97.0	±0.44		41.5	±0.18		42.0	±4.00		18.5	±3.01		19.0	±5.24	
Oct 22.....	93.5	±2.27		98.0	±1.48		42.0	±0.90		42.5	±2.86		18.5	±3.01		21.0	±4.74	
Oct 31.....	88.7	±2.98		97.3	±0.75		40.0	±3.90		45.0	±2.86		19.8	±3.80		20.7	±3.24	
Average....	91.425	±2.27		96.575	±1.09		41.625	±2.07		43.75	±3.43		19.075	±3.01		20.05	±3.99	

(15 per cent SO_3); and (c), 50 per cent sulfuric acid solution made by diluting concentrated sulfuric acid (95 per cent H_2SO_4) with an equal volume of water.

Preparation of Standard.—Put 1 cubic centimeter of .03125 per cent sucrose solution into the bottom of a 25 cubic centimeter test tube by means of a pipette, without wetting the side of the tube. Add fairly rapidly, with medium shaking, 2 cubic centimeters of fuming sulfuric acid (15 per cent SO_3). After 15 to 20 minutes, make the brown solution which results, to 20 cubic centimeters with 50 per cent by volume sulfuric acid. Mix well and read in a colorimeter at least 3 hours after dilution. Standing over night seems to be best. Some time is needed for the solution to cool so that air bubbles do not interfere, and proper dispersion is completed. One cubic centimeter of this solution contains .00658 milligram of C.

Treatment of Plant Extract.—Treat 1 cubic centimeter of the clear plant extract (1, 4) exactly as was done with the standard solution and at about the same time. The volume should be made to a volume that brings the unknown fairly close to the standard in color. If too dark a color is produced, the extract should be diluted before treatment. If the color is too light, a larger original plant sample should be used.

The amount of carbon in the 3 cubic centimeter volume at the end of the treatment with fuming acid should not be so great that carbon is precipitated. It is easy to dilute the extract so that precipitation does not occur.

Calculation of Carbon in Plant Extract.—On testing different concentrations of sucrose and glucose solutions, it was apparent that there was a small deviation from Beer's law, or from a directly proportional line relationship. The results of readings on an electric colorimeter (Klett Summerson No. 114) are given in Table I. It will be seen that the readings on the three different concentrations of sugars were not quite proportional to the dilution. However, when the larger reading was divided by the lower, very nearly the same ratio of 2.2 was found as shown in Table II. If the relationship were direct, the ratio would have been 2.0. The fact that we always get 2.2 with all dilutions and with both sugars, shows that while the color diminished more rapidly than the carbohydrate, the change in color was uniform.

TABLE II—RATIO OF AVERAGE COLORIMETER READINGS GIVEN BY GLUCOSE AND SUCROSE

Concentration of Solutions (Per Cent)	0.0625 Diluted to 0.03125		0.03125 Diluted to 0.015625	
	Readings			
With glucose.....	91.425	41.625	41.625	19.075
Ratios.....	2.196		2.182	
With sucrose.....	96.575	43.75	43.75	20.05
Ratios.....	2.207		2.196	

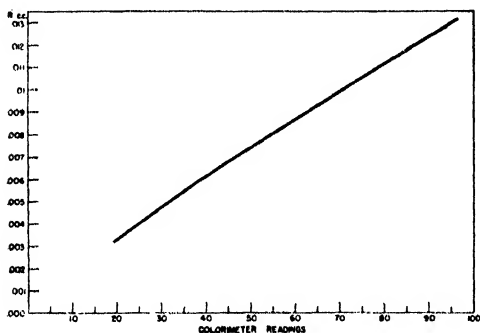


FIG. 1. "The line of relationship between concentration of carbon and colorimetric readings showing a small constant deviation from Beer's Law".

This being the case, the graph (Fig. 1) was constructed in which concentration of carbon is plotted against the colorimetric reading. Both glucose and sucrose readings fit into the deviation curve.

To find the concentration of carbon, the reading of the unknown is found on the graph and the concentration of sugar is read from the curve. Sucrose was used as a standard since glucose tended to give slight pink-

ish tints while the color from sucrose always compared well with that from the plant extracts.

Also, the concentration of carbon may be found by making up several dilutions of sucrose and obtaining the average readings for each dilution, as was done in Table I. In calculating the concentration of the unknown, the dilution of standard which is closest to the unknown should be used. The closer the reading of the unknown is to that of the standard, the more accurate the calculation will be.

RATIO BETWEEN THE COLORIMETRIC READINGS GIVEN BY GLUCOSE AND SUCROSE

The theoretical concentration in 1 cubic centimeter of a .03125 per cent glucose solution made to 20 cubic centimeters is .00625 milligram of carbon per cubic centimeter, while that of sucrose is .00658 milli-

gram. Then the ratio of carbon in sucrose to glucose is $\frac{.00658}{.00625} = 1.0526$.

When we take the ratios of the average readings of carbon in sucrose to that in glucose, (Table II), $\frac{43.75}{41.625}$ we get 1.051. If we find the

ratios of the readings of the other concentrations in like manner, we get 1.056 for .0625 per cent and 1.051 for .01563 per cent. The average of all the ratios is 1.0527 which is very near the theoretical ratio of 1.0526. This close agreement with the theoretical gives definite proof that the method is quite accurate in detecting small differences in carbon content.

CAUSE FOR THE DEVIATION CONSTANT

Since we have the deviation constant of 2.2 between solutions which should be twice each other, a test was made to determine the cause for this. If a solution was treated with acid, diluted to 20 cubic centimeters and then 10 cubic centimeters of this was diluted to 20 cubic

TABLE III—COLORIMETRIC READINGS AND RATIOS OF GLUCOSE AND SUCROSE SOLUTIONS VARIED BY DIRECT DILUTION*

No. 1	No. 2	No. 3	Ratios	
0.0625 Per Cent Glucose	No. 1 Diluted One-Half	No. 2 Diluted One-Half	No. 1 No. 2	No. 2 No. 3
103.0	52.0	26.5	1.98	1.96
103.0	51.0	26.0	2.02	1.96
102.0	50.0	25.5	2.04	1.96
104.0	52.0	26.0	2.00	2.00
99.0	50.0	24.5	1.98	2.04
104.0	51.0	25.5	2.04	2.00
Average 102.5	51.0	25.67	2.01	1.99
0.03125 Per Cent Glucose	No. 1 Diluted One-Half	No. 2 Diluted One-Half	No. 1 No. 2	No. 2 No. 3
42.0	22.5	11.0	1.87	2.05
41.0	21.0	10.5	1.95	2.00
44.0	22.0	11.0	2.00	2.00
41.0	21.0	10.5	1.95	2.00
44.0	22.0	11.5	2.00	1.91
44.0	22.0	11.0	2.00	2.00
Average 42.67	21.75	10.92	1.96	1.99
0.0625 Per Cent Sucrose	No. 1 Diluted One-Half	No. 2 Diluted One-Half	No. 1 No. 2	No. 2 No. 3
99.0	48.0	24.0	2.06	2.00
100.0	50.0	25.0	2.00	2.00
101.0	51.0	25.0	1.98	2.04
101.0	51.0	25.0	1.98	2.04
101.0	50.0	24.5	2.02	2.04
101.0	50.0	25.5	2.02	1.96
Average 100.5	50.0	24.83	2.01	2.01
0.03125 Per Cent Sucrose	No. 1 Diluted One-Half	No. 2 Diluted One-Half	No. 1 No. 2	No. 2 No. 3
42.0	22.0	11.0	1.91	2.00
43.0	21.0	10.5	2.05	2.00
44.0	22.0	10.5	2.00	2.10
42.0	21.0	11.0	2.00	1.91
42.0	21.5	10.5	1.95	2.05
41.0	20.0	10.5	2.05	1.90
Average 42.33	21.25	10.67	1.99	1.99

*Sugar solutions which were several days old were used in these determinations and bacterial action had caused some changes so that these readings are not comparable with those of the freshly made solutions in Table I.

centimeters again with 50 per cent sulfuric acid, the one solution should read twice as much as the other if the color dilutions were proportional and followed Beer's law. Table III gives results of this procedure on all concentrations of standard used. In all cases the ratio was very nearly 2, showing that the color dilutions followed Beer's law very closely. This gives definite indication that the deviation is due to slightly greater oxidation in the weaker solutions than in the stronger. By using the graph, this effect can be overcome. It would be an advantage to the method however, if this oxidation, although small, could be prevented. Experimental work is planned to try the addition of certain reducing agents to stop the oxidation and still allow full carbonization of the carbohydrates to take place.

CONCENTRATION OF CARBON FOUND IN EQUAL ALIQUOTS OF EXTRACTS FROM APPLE AND PEACH TWIGS

Table IV gives the readings for equal aliquots of extracts from various samples of apple and peach twigs, and was done to test the accuracy of the method on samples from the same plant extract.

TABLE IV—CARBON IN THE EXTRACT FROM APPLE AND PEACH TWIGS,
(EXPRESSED AS PARTS PER MILLION OF GREEN WEIGHT)

Sample No.	Kind of Tree	Colorimeter Reading	Carbon (Ppm)	Deviation From Mean (Per Cent)
1a	Golden Jubilee peach, millet cover	44.0	1323.5	
1b	Golden Jubilee peach, millet cover	42.0	1263.3	±2.33
2a	Delicious apple, millet cover	26.0	853.2	
2b	Delicious apple, millet cover	23.0	754.8	±6.12
3a	Winesap apple, millet cover	48.0	1443.8	
3b	Winesap apple, millet cover	45.0	1353.6	±3.22
4a	Rome Beauty apple, millet cover	41.0	1233.3	
4b	Rome Beauty apple, millet cover	42.0	1263.3	±1.20
5a	Golden Jubilee peach, grass sod	53.0	1594.2	
5b	Golden Jubilee peach, grass sod	51.0	1534.1	±1.92
6a	Delicious apple, grass sod	38.0	1143.0	
6b	Delicious apple, grass sod	38.0	1143.0	0.00
7a	Winesap apple, grass sod	39.0	1173.1	
7b	Winesap apple, grass sod	37.0	1112.9	±2.63
8a	Rome Beauty apple, grass sod	30.0	984.5	
8b	Rome Beauty apple, grass sod	30.0	984.5	0.00
9a	Golden Jubilee peach, sweet clover	48.0	1443.8	
9b	Golden Jubilee peach, sweet clover	50.0	1504.0	±2.04
10a	Mikado peach, lespedeza	75.0	2044.0	
10b	Mikado peach, lespedeza	78.0	2125.8	±1.96

Samples a and b are equal aliquots from the same extract, obtained as described in a previous paper (4). The highest deviation from the mean occurred in the Delicious apple; this being 6.13 per cent. The rest were all below 3.22 per cent.

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The Influence of Methods of Heating and Covering Electric Hotbeds on Field Production of Vegetables¹

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PERENNIAL interest is manifested by northern vegetable growers in hastening the early growth of small plants by the use of hotbeds to produce earlier crops in the field and derive a benefit from the higher market prices. In the past, these hotbeds have almost invariably been heated by fermenting manure. This was probably due to the fact that manure was cheap and readily available. However, many growers in recent years have turned to electricity for soil heating, partly because mechanization of farm operations has made good manure scarce and more costly, but mainly because electric service has become more available in rural areas at reasonably low cost to the consumer. A detailed study, under present day conditions, of the relative effects of electric cable and incandescent lamp methods of hotbed heating and film as compared to glass covered hotbeds on the plant growth and ultimate yield in the field is reported in this paper.

METHODS AND RESULTS

Eight four-sash hotbeds were used in this experiment; four for the cool season crops (lettuce, cabbage and cauliflower) and four for the warm season crops (tomatoes, eggplants and peppers). Two of the cool season hotbeds and two of the warm season hotbeds were covered with cellulose acetate and the other four hotbeds were covered with glass.

One of the cool season hotbeds and one of the warm season hotbeds covered with cellulose acetate were heated with incandescent lamps and the others with the same cover were heated with electric heating cable. An equal number of glass-covered hotbeds were heated in the same manner as the cellulose acetate-covered hotbeds.

Eight 25-watt inside frosted A-19 bulb Mazda B lamps were used to heat each 3 x 6 feet sash on the hotbeds heated by incandescent lamps. All of these lamps were connected to a thermostat-controlled circuit with a check watt-hour meter. These lamps, fitted with inexpensive porcelain sockets, were mounted on 8½-inch centers to the under side of a 6-foot removable wooden strip which spanned the bed just beneath the center of the sash.

Two 60-foot cables (400 watts each) were installed in each of the four-sash cable heated hotbeds and connected to one thermostat-controlled circuit with a check watt-hour meter. The cable was laid near the surface of the soil in accordance with best practices of spacing recommended by the manufacturer and covered with a wire screen for protection.

¹C. I. Bliss, Biometritition at Storrs and Connecticut Agricultural Experiment Stations, assisted in the statistical calculations. R. L. Zahour, Research Engineer with the Connecticut Light & Power Company, assisted with the electrical phases of the study.

These cool and warm season crops were planted in flats under each of these treatments and replicated at random in the beds. There were eight flats of each vegetable in every one of the treatments and the plants from these flats were randomized in the field, making eight replications of each vegetable for field study. The beds for the cool season crops were maintained at 50 degrees F and those for the warm season crops at 60 degrees F in the thermostat-controlled hotbeds.

Undoubtedly, one of the more important considerations in an experiment of this kind is the comparative costs of construction and operation of the hotbeds. Uniform methods of construction were used for each bed. An attempt was made to standardize the beds using glass sash before the plants were started. The thermostats were in each bed set so as to maintain the same temperature 50 or 60 degrees F as indicated above. Each bed was watered uniformly at the same time and the amount of labor for maintaining the beds was kept at a minimum. Figuring on the cost of the materials at the time of construction (1938) it cost 20 per cent less to construct an incandescent lamp heated hotbed than an electrical soil-heating cable hotbed. The cost of electric current for the lamp-heated beds has consistently been 35 per cent less than the costs of cable-heated beds. The hotbed sash covered with film will cost \$1.10 less per sash than the glass covered ones, but will cost about \$1.00 every 5 to 10 years for coverage replacement. The influence of the lower cost of the lamp heated electric hotbeds over the cable heated type is of such a magnitude as to be of a definite consideration when constructing an electric hot bed.

The two variables, methods of heating and covering of sash were carefully considered in determining the field results.

Field data on warm season crops were obtained on the number and size of early tomatoes produced before August 14th and the total number and size of tomatoes, peppers and eggplants produced over the entire season. The average weight per head, the density per head for cabbage and lettuce, the average width for cauliflower and the percentage of crop harvested at the first cutting for lettuce were recorded in the field for all cool season crops. Table I indicates the grade of

TABLE I—MEAN SQUARES FROM ANALYSIS OF VARIANCE FOR GRADE OF FRUITS PRODUCED IN TERMS OF AVERAGE WEIGHT PER FRUIT (WARM SEASON CROPS) AND HEAD DENSITY (CABBAGE, LETTUCE) OR HEAD WIDTH (CAULIFLOWER)

Variation Due to:	D.F.	Warm Season Crops				Cool Season Crops		
		Tomatoes		Egg-plants	Peppers	Cabbage	Cauliflower	Lettuce
		Weight Early	Weight Total	Weight Total	Weight Total	Head Density	Head Width	Head Density
Blocks.....	7	846	929	1350	255	26	365	810
Cable vs. bulbs.....	1	3	310	26	12	72	878*	263
Glass vs. film.....	1	378	310	88	200	136	138	3578*
Interaction.....	1	703	700	5	50	10	15	90
Error.....	21	385	346	188	268	72	122	627

*Significant.

TABLE II—MEAN SQUARES FROM ANALYSIS OF VARIANCE FOR YIELDS MEASURED IN TERMS OF NUMBERS OF FRUIT (WARM SEASON CROPS) AND OF HEAD WEIGHT (COOL SEASON CROPS)

Variation due to:	D.F.	Warm Season Crops				Cool Season Crops			Per Cent 1st Cutting
		Tomatoes		Egg-plants	Pep-pers	Cab-bage	Cauli-flower	Let-tuce	
		No. Early	Total No.	Total No.	Total No.	Weight	Weight	Weight	
Blocks.....	7	477	2906	315	271	147	1000	161	1077
Cable vs. bulbs...	1	945*	802*	1391*	1058	90	1378	58	338
Glass vs. film...	1	1015*	0	1682*	24	113	0	132	21
Interaction.....	1	383	503*	328	18	25	28	60	0
Error.....	21	212	112	163	825	99	389	137	134

*Significant.

TABLE III—MEAN YIELDS PER PLOT UNDER EACH TREATMENT

Vegetable	Average Number of Plants Per Plot	Cable-Film		Cable-Glass		Bulbs-Film		Bulbs-Glass	
		Number of Fruit	Weight of Fruit (Lbs)	Number of Fruit	Weight of Fruit (Lbs)	Number of Fruit	Weight of Fruit (Lbs)	Number of Fruit	Weight of Fruit (Lbs)
Tomatoes...	18	351.25	86.75	306.62	72.36	331.75	82.27	338.75	83.67
Peppers...	18	175.25	41.18	178.50	42.30	165.25	38.50	165.50	39.88
Eggplants	18	81.25	101.15	96.75	122.87	67.60	84.83	81.12	105.13

TABLE IV—MEAN WEIGHT OF HEADS PER PLOT UNDER EACH TREATMENT

Vegetable	Average Number Plants Per Plot	Cable-Film (lbs)	Cable-Glass (Lbs)	Bulbs-Film (Lbs)	Bulbs-Glass (Lbs)
Cabbage (one wrap leaf)...	40	112.00	114.40	114.00	120.80
Cauliflower (green border)...	40	68.40	67.20	72.80	73.20
Lettuce (one wrap leaf)...	47	47.47	50.76	47.47	47.94

vegetables produced and Table II is considered as a criterion of the yield.

In Table I there appears to be no difference in the quality of warm season crops. The following significant results can be seen in this table on the cold season crops; (lettuce) film is definitely better than glass for coverage; (cauliflower) bulbs are much better than cable for heat. The indications are that from the standpoint of quality, cool season crops favor bulbs and film for plant production.

The yield of the warm season crops was significantly better from cable hot-bed produced plants. The increased yield does not justify the cost of cable heat as compared with bulb heat. There were no noticeable yield effects on the cool season crops, except bulb hotbed lettuce plants approached significance for field earliness in terms of percentage harvested the first cutting. The interaction between bulbs versus cable for all crops is not influenced by the glass versus film except the total number of tomatoes with cable-glass are significantly more effective

than when bulbs and film are used. The field data on all these crops, in general, are satisfactory for all treatments considered, but the cost of construction and maintenance of these types of electric hotbeds appears to be more of a determining factor in selecting an electric hot bed.

In conclusion, it appears that incandescent lamps for heat and cellulose acetate film for sash covering are worthy of consideration for use in hotbeds where early plants are to be grown for field planting.

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A Study of Methods of Planting Beets

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RATHER extensive vegetable variety (strain and stock) trials have been carried on at the University of Connecticut. Relative to such crops as beets, carrots and radish, interested workers have not agreed as to the most desirable method of planting for trial purposes; that is, (a) should a heavy seeding be made with subsequent thinning or (b) should we plant only enough seed to give the proper spacing in the row. It has been pointed out that if the first method is used the weak seedlings, including also perhaps certain off-type plants, are removed from the experiment. If this were true, the method used would be important when seed stocks are tested, and relatively less important when varieties or strains are considered. On the other hand, the first method is often used by the grower and, therefore, it may be claimed that it is the more desirable of the two. If the second method is used, no weak or off-type seedlings are eliminated by thinning, and it might be said that the seed samples planted are tested one against the other. Thus, at least for testing stocks, this method might be the more desirable. An experiment to determine if the two methods did actually give different results was planned.

The two methods were compared in a randomized block arrangement of plots. Procedure for method 1 (thinned) consisted of seeding an excess of seed with subsequent thinning out of seedling plants to give the required stand in the row. For method 2 (seeded), the required stand in the row was obtained by planting the required number of seeds (highly viable seed was used). The two methods were compared at several different spacings in the row; 1 inch, 1.5 inch, 2 inches, 2.5 inches, 3 inches, 3.5 inches and 4 inches. Thus, the experiment in reality was also a study of spacing in the row. The plots, a single row 10 feet long, were replicated four times. An early crop and a late crop of two varieties were grown in 1940. All data were collected at harvest, which was made at the bunching state.

Data were obtained on the number of marketable roots in the different treatments and on the weight of roots in the different treatments. Any root that had attained a specified size, (that is, salable bunching size) and was not deformed was considered as marketable. These data are presented with the aid of a graph in Fig. 1 and the analysis of variance and covariance are given in Table I (early crop) and Table II (late crop).

EXPERIMENTAL RESULTS AND DISCUSSION

The two varieties used in the experiment were found to differ significantly in production of marketable roots, in weight of marketable roots and also in weight of roots when the effect of number had been eliminated (line 2 of the tables).

The number of marketable roots produced in the two methods of planting varied significantly in both crops (line 3). In the early crop,

TABLE I—ANALYSIS OF VARIANCE AND COVARIANCE FOR THE NUMBER OF MARKETABLE ROOTS (X) AND THE WEIGHT OF MARKETABLE ROOTS (Y) IN THE EARLY CROP

	D.F.	X ²	XY	Y ²	Mean X ²	Mean Y ²	Adj. Y ²	Adj. Mean Y ²
Blocks	3	335.7	82.61	47.855	111.9*	15.96†		
Varieties	1	299.0	115.02	44.251	299.0†	44.25†	40.578	40.578†
Methods of planting	1	412.7	30.90	2.401	412.7†	2.40	1.468	1.468
Varieties × method of planting	1	0.7	0.93	1.201	0.7	1.20	1.171	1.171
Distance linear	1	3024.3	102.89	3.500	3024.3†	3.50	0.660	0.660
Distance remainder	5	100.1	17.34	4.428	20.0	0.89	3.893	0.779
Distance × varieties linear	1	58.6	6.80	0.789	58.6	0.79	0.578	0.578
Distance × varieties remainder	5	221.4	46.06	11.880	44.3	2.38	10.448	2.089
Distance × method of planting linear	1	2.9	1.00	0.343	2.9	0.34	0.311	0.311
Distance × method of planting remainder	5	39.9	14.62	6.441	8.0	1.29	5.978	1.196
Distance × varieties × method of planting linear	1	58.6	8.10	1.120	58.6	1.12	0.867	0.868
Distance × varieties × method of planting remainder	5	389.6	52.43	15.129	77.9	3.03	13.535	2.707
Error	81	2809.5	45.45	105.062	34.7	1.30	104.046	1.285
Total	111	7753.0	524.15	244.400				

*Significant at 5 per cent level.

†Significant at 1 per cent level.

TABLE II—ANALYSIS OF VARIANCE AND COVARIANCE FOR THE NUMBER OF MARKETABLE ROOTS (X) AND WEIGHT OF MARKETABLE (Y) ROOTS IN THE LATE CROP

	D.F.	X ²	XY	Y ²	Mean X ²	Mean Y ²	Adj. Y ²	Adj. Mean Y ²	Red. Y ²
Blocks	3	90.3	79.05	23.358					
Varieties	1	114.0	34.51	10.443	114.0*	10.44†	5.495	5.495*	—
Method of planting	1	144.0	41.96	12.223	144.0*	12.22†	6.244	6.244†	—
Varieties × method of planting	1	9.7	2.59	0.691	9.7	0.69	0.328	0.328	—
Distance linear	1	215.9	3.26	0.049	215.9†	0.05	0.998	0.998	—
Distance remainder	5	89.3	7.79	1.390	17.9	0.28	0.701	0.140	—
Distance × varieties linear	1	62.3	12.86	2.657	62.3	2.66	0.950	0.950	—
Distance × varieties remainder	5	85.1	12.85	4.180	17.0	0.84	4.554	0.911	—
Distance × method of planting, linear	1	227.1	52.05	11.928	227.1†	11.93†	4.846	4.846	4.231
Distance × method of planting remainder	5	206.6	39.74	8.384	41.3	1.68	3.205	0.641	—
Distance × varieties × method of planting linear	1	8.6	1.14	0.146	8.6	0.15	0.016	0.016	—
Distance × varieties × method of planting remainder	5	88.0	10.69	2.660	17.6	0.53	1.491	0.298	—
Error	81	1566.0	130.13	80.710	19.3	1.00	69.896	0.863	—
Total	111	2006.9	428.62	158.819					

*Significant at 5 per cent level.

†Significant at 1 per cent level.

the greater number is in the seeded method, as may be noted in the graph, while in the late crop the thinned method produced the greater number. Inasmuch as the difference was not in the same direction in the two crops, it cannot be said that either tends to produce the greater number of marketable roots and whether or not the seasonal effect found in the experiment would hold in all cases cannot be ascertained. In the early crop the yield in weight of marketable roots did not vary

in the methods of planting. In the late crop a significant difference was found. The graph (Fig. 1) suggests that the yield varies directly

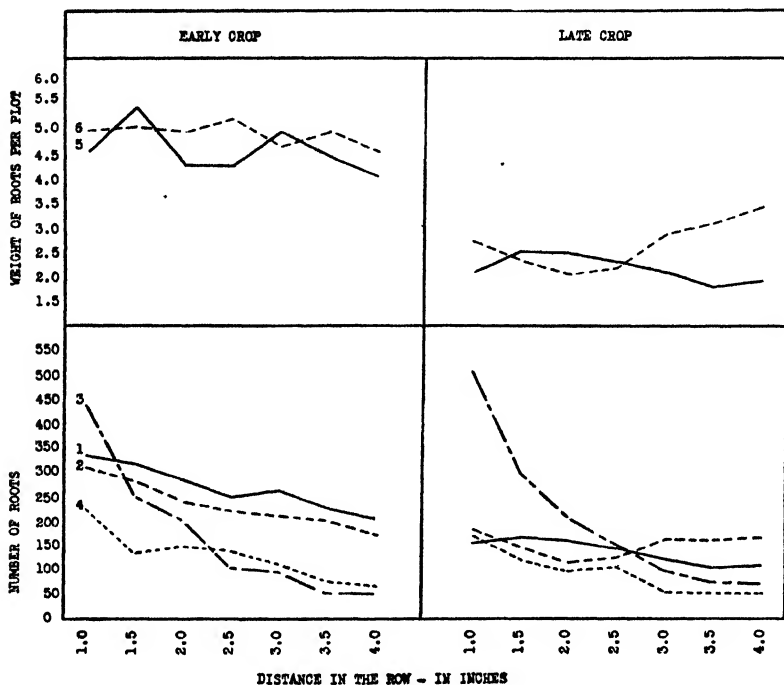


FIG. 1. The relation between "method of planting", and "distance in the row" relative to number of marketable roots, number of unmarketable roots and total weight of roots. 1, Seeded—number of marketable roots; 2, thinned—number of marketable roots; 3, seeded—number of unmarketable roots; 4, thinned—number of unmarketable roots; 5, seeded—average weight of root per plot; 6, thinned—average weight of root per plot.

with the number of marketable roots; however, the adjusted mean square is significant showing that the yield in weight varied after the effect of number had been eliminated.

The varieties were found to behave similarly in the two methods of planting (line 4).

A direct significant increase in number of marketable roots was obtained as the distance apart of plants in the row was decreased (lines 5 and 6). This is readily discernible in the graph of the early crop, but is not especially apparent in the late crop. The portion of variation due to curvature from the straight line is not significant. It is somewhat surprising to find that the very closest distance in the row, 1 inch, produced the greatest number of marketable roots. Obviously, this 1-inch distance in the row is very close to the point beyond which no increase would be obtained. The yield in weight did not increase significantly with a decrease in distance apart of the plants in the row

in either crop. In the early crop, however, an inspection of the data suggested that the close spacing in the row tended to produce a greater yield in weight. There is no suggestion of this tendency in the late crop. Elimination of the effect of number of marketable roots upon yield in weight does not appear to cause the variation in yield in the several distances apart in the row to become significant.

The varieties used responded in a similar manner at the several different spacings in the row (lines 7 and 8). Thus, in testing these varieties for yield (number of marketable roots or weight of marketable roots) the spacing distance in the row that is selected is not of great importance.

In the early crop, the results obtained from the two methods of planting at each of the different spacings in the row were similar (lines 9 and 10). The graph shows this relationship as the difference between two approximately straight lines, the spaced method yielding a constant greater number of roots at each spacing. In the late crop the results from the two methods of planting were different at the different spacings in the row, and, as may be noted in the graph, the lines that represent the methods of planting cross each other at two points. Thus, the data may be taken to suggest that there is a seasonal effect. On the other hand, it may be questionable if the data are sufficient to draw such a conclusion and rather, such a discrepancy would be no greater than expected in a random samples. When the effect of number of marketable roots on yield in weight is eliminated, the difference in yield is not significant, that is, the difference in yield is due primarily to greater numbers.

In conclusion, although differences are found in the varieties, in the results from the methods of planting and in the interactions of distance in the row by method of planting (late crop only), we cannot say that it would make any difference which method were used to test varieties for the variety by method of planting interaction is non-significant. In other words, if other varieties respond as those used in this experiment, then the method of planting used is not important. However, it would be inadvisable to employ both methods in a single variety test. To give an answer the portion of the problem relative to testing strains and stocks would necessitate the extension of the experiment to include several strains and several stocks of a strain or variety.

From a grower's point of view, the treatment that gives the greatest net return is important. In this study, the variation in yield in the several treatments is actually surprisingly small. Beets do not appear to be especially sensitive to these treatments and the treatment recommended would depend upon the cost of seed, what the crop is to be used for and so on.

Several other factors were considered in the study such as color of skin, color of flesh and per cent zoning. Technique, relative to methods of evaluating the characters, apparently are not refined or developed enough to make it possible to detect small differences.

The Carotene Content of Sweet Potatoes¹

By H. L. COCHRAN, *Georgia Agricultural Experiment Station, Experiment, Ga.*

CAROTENE is the principal yellow pigment found in sweet potatoes which when taken into the body is converted into vitamin A. It is this compound that performs many important biological functions which are essential to the good health of both man and animal.

Steenbock and Sell (15) working in Wisconsin in 1922 studied the vitamin A content of three varieties of sweet potatoes namely, Triumph, one with a creamy white flesh; Little Stem Jersey, with flesh of a light yellow color; and Nancy Hall, a variety with flesh of a more intense yellow color. It was reported from the data secured that the amount of vitamin A found varied with the depth of color. In 1931 Rice and Munsell (14), as cited by MacLeod *et al.* (9) reported the vitamin A content of the sweet potatoes used by them to be 1,360 Sherman units per pound of sample. By following the Sherman and Munsell method Hessler and Cole (4) reported that 0.12 grams of the Nancy Hall variety of sweet potato as used in their work contained one unit of vitamin A. MacLeod, Talbert, and Toole (10) found the Nancy Hall variety to contain approximately 30 units of vitamin A per gram of material.

Swanson, Nelson, and Haber (16) working at Ames, Iowa, studied the effect of varying known fertilizer treatments of nitrogen, phosphorus, potash, and manure on the vitamin A content of a prolific but unnamed variety of sweet potato. It was found that the quantity of vitamin A in the potatoes fertilized with manure was approximately twice that present in those grown with no nutrients added to the soil. Potatoes receiving the other fertilizer treatments were found to be intermediate in quantities of vitamin A. This work was continued and reported on further in 1933. When 35 milligrams of sweet potatoes were fed daily to white rats, the average weekly gain of the experimental animals receiving potatoes from the various fertilizer treatments were as follows: manure fertilized, 6.2 grams; unfertilized, 6.2 grams; potash alone, 5.8 grams; nitrogen alone 4.7 grams; phosphorus alone 4.6 grams. The final conclusion of the authors upon a statistical analysis of the data was that no significant difference between the gains was demonstrated. Fraps and Treichler (2) found Porto Rico sweet potatoes to be an excellent source of vitamin A. From 30 to 40 units were reported per gram of raw sample. Dr. W. C. Sherman of Alabama Polytechnic Institute analyzed Porto Rico and Nancy Hall sweet potatoes for carotene that were furnished by Dr. Florence MacLeod (8) of the Tennessee Agricultural Experiment Station in 1938 and 1939. During the first year of this work 53.8 micrograms of carotene per gram of fresh material were found in the Porto Rico variety while only 27.5 micrograms per gram were reported in the Nancy Hall. In 1939, 54.5 micrograms per gram were found in the Porto Rico and 31.9 in the Nancy Hall.

¹The author wishes to express his appreciation to those workers cited for furnishing many of the data used in this paper.

EFFECT OF STORAGE OF SWEET POTATOES ON THEIR CAROTENE AND VITAMIN A CONTENT

MacLeod, Armstrong, Heap, and Talbert (9) working in Tennessee studied the vitamin A content of different types of sweet potatoes commonly grown in that state. Three of the varieties studied, the Nancy Hall, Yellow Jersey and Porto Rico, are strongly pigmented, the Porto Rico having the deepest color and the Nancy Hall and Yellow Jersey having about the same depth of color. The Triumph and Southern Queen are very much lighter, in fact almost white, in color. The Porto Rico and Yellow Jersey varieties were sampled at two different dates, first immediately after harvest in the fall and again 2 months later. The Nancy Hall, Triumph, and Southern Queen varieties were sampled only after they had been cured and stored for sometime. Under the conditions of these experiments the data presented show the variety Nancy Hall to contain 30 units of vitamin A per gram of sample, the Triumph 2 units per gram and the Southern Queen 4 units per gram of material. The Porto Rico variety was found to contain 20 units of vitamin A per gram directly after harvest, but after 2 months in storage contained 65 units or more than three times the original value. Likewise the variety Yellow Jersey was found to contain only 10 units of vitamin A per gram immediately after harvest and 40 units or four times as much after 2 months in storage. These data are confirmed by the work of Miller and Covington (12) who used the Porto Rico variety and took samples for carotene determinations at harvest time, 1 month after harvest, 2 months after harvest, and 3 months after harvest. These data are presented in Table I.

TABLE I—THE EFFECT OF STORAGE ON THE CAROTENE CONTENT OF PORTO RICO SWEET POTATOES†

Time of Determination	Amount of Carotene* (Micrograms per Gram Sample)
At harvest.....	51.0
1 month after harvest.....	75.3
2 months after harvest.....	81.9
3 months after harvest.....	80.2
*Difference required for significance.....	5.6

†Used with the permission of Miller and Covington and taken from a paper published in volume 40 of the Proceedings of the American Society for Horticultural Science.

It is evident from these data that there was a significant increase in the carotene content of the roots from the first until the third month in storage. Had MacLeod *et al.* (9) extended their storage period longer than 2 months it is possible that the same condition would have existed. Although Miller and Covington offer no explanation for the increase of carotene in the roots during storage, MacLeod *et al.* were of the opinion that this condition may result from one of three possible reasons, first that the carotene is not fully developed when the roots are first harvested; second that the carotene has not yet developed into

the precursor of vitamin A; and third that this precursor (the carotene responsible for the formation of vitamin A *in vivo*) is present in a form less available to the animal body when the sweet potatoes are first harvested than after they have been stored for sometime.

THE STABILITY OF CAROTENE AND VITAMIN A IN SWEET POTATOES

Since Porto Rico sweet potatoes have been found to be an excellent source of carotene (6) interest has been revived and a great deal of work conducted within recent years on the loss of the latter compound in the manufacture of various sweet potato products, some of which are now used as food for man and other as feed for livestock.

The extensive work of Caldwell, Moon, and Culpepper (1) on the suitability of a large number of varieties of sweet potatoes for drying purposes indicates that if the material is improperly prepared and dried serious losses in depth of color may result. In this same connection results of work reported by Fraps and Treichler (2) show a 29 per cent loss in vitamin A from sweet potatoes that had been ground and dried for 7 hours at 100 degrees C.

Lease and Mitchell (6) have reported results of studies on the nutritive value of dehydrated sweet potatoes. These workers are of the opinion that the dehydration process has promise of a practical means of preserving for suitable utilization excess sweet potatoes and sweet potato culls that usually comprise a large per cent of the entire crop. Sweet potato flour prepared from the variety Porto Rico was found to contain on the average of 130 micrograms of carotene per gram of material. The milk of cows fed a low vitamin A ration plus sweet potato flour showed an increase in the carotene and vitamin A content. When chickens were fed on a low vitamin A ration plus this material, considerable quantities of vitamin A were stored in their livers as was the case with young calves when fed the flour in skimmed milk. It was also reported in this work that sweet potato flour added greatly to the vitamin A potency of certain food products made from the flour, and practically all of the potency was present after the foods were stored for a period of 3 weeks.

By far the most extensive work on the stability of carotene in dried sweet potatoes is that conducted by Mitchell and Lease (13) at Clemson College, South Carolina. Since the carotene content of sweet potatoes has been found to decompose rather rapidly under ordinary storage conditions these authors were interested not only in the rate of this decomposition under various conditions, but also in methods by which the carotene may be preserved. The variety Porto Rico was used and dehydrated by cutting the unpeeled roots into slices about 2 millimeters thick and immediately exposing them to a current of dry air at 70 to 80 degrees C. Sweet potato flour was prepared from this material and then hermetically sealed in various inert atmospheres. Samples were taken for carotene determinations just before sealing and at the end of 4, 8, and 12 months time. These results are presented in Table II. It is to be noted that when sweet potato flour is stored for several

TABLE II—STABILITY OF CAROTENE IN SWEET POTATO FLOUR AS AFFECTED BY METHOD OF STORAGE*

Method of Packing	Carotene Content After Various Storage Periods (Micrograms Per Gram)				Loss During 1 Year (Per Cent)
	Initial	4 Months	8 Months	12 Months	
In hermetically sealed cans					
Under carbondioxide.....	158	119.0	119.0	131.0	17.1
Under nitrogen.....	158	119.0	128.0	119.0	24.0
Vacuum (15 mm).....	158	—	123.0	119.0	24.0
Sealed in air.....	158	—	17.3	17.4	89.0
In loosely stopped bottles.....	158	8.8	5.37	2.37	98.5

*Used with the permission of Mitchell and Lease and taken from S. C. Agr. Exp. Sta. Bul. 233. 1941.

months in contact with air regardless of the container, it lost a large percentage of its carotene. However, when the air was replaced by carbondioxide, the carotene was very stable. The carotene was also found to remain stable for rather long periods of time without serious losses if the air was evacuated before sealing. In fact, 76 per cent of the original carotene content of the flour was still present after storage for 12 months in vacuum-sealed metal cans. Curves presented by the authors indicate that crude cottonseed oil has a definite preserving effect on the carotene of sweet potato flour as evidenced by the fact that after 4 months untreated flour stored at room temperature contained only 32 micrograms of carotene per gram of material while that treated with cottonseed oil contained 92 micrograms per gram. The carotene in raw sweet potatoes was found to be more stable than the carotene in sweet potato flour.

Work conducted by Lease and Mitchell (7) show that there are certain carbohydrates in the sweet potato which might interfere with the determination of carotene. In samples containing large quantities of carbohydrates the authors present data to show that the carotene may be satisfactorily determined by extraction with ethanol. If, however, alcoholic potassium hydroxide is used, the authors state that the material should first be boiled with water to dissolve the resins before extraction of the carotene by fat solvents.

EFFECT OF BREEDING ON THE CAROTENE CONTENT OF SWEET POTATOES

From the data presented thus far it is evident that the yellower the potato the more carotene it contains, and of the named varieties grown commercially today, Porto Rico is one of the highest yielders of carotene.

Since the epic findings of Miller in 1937 (11) of methods for inducing the sweet potato to bloom and set seed, carotene has served as a basis for a far reaching program of research on improving the edible quality of this crop through the process of breeding. One of the primary purposes of this work was to breed for a sweet potato having a high carotene content. Today much has been accomplished along this line at the Louisiana Agricultural Experiment Station under field conditions and under greenhouse conditions at the United States

Horticultural Station at Beltsville, Maryland. Since the parental stock used so far has been found to be quite heterozygous, there has resulted much segregation even in the F_1 generation hybrids. Some of the more promising seedlings resulting from crosses made by Miller and Covington (12) at the Louisiana Station are shown in Table III.

TABLE III—CAROTENE CONTENT OF SWEET POTATO SEEDLINGS AND THEIR PARENTS†

Seedlings or Variety	Carotene Content*	Seedling or Variety	Carotene Content*
1 X 6-39-2	87.8	32-87-20	96.4
1 X 6-36-6	151.5	32-106-25	41.8
1 X 42-39-3	57.8	32-149-36	85.1
1 X 6-38-14	41.3	Selected Parents	
3 X 6-39-2	86.4		
3 X 7-39-1	72.2	Unit I Porto Rico (No. 1)	76.3
6 X 1-39-6	87.9	Nancy Hall (No. 6)	28.3
7 X 63-39-4	129.5	47442 (No. 42)	27.6
42 X 6-39-12	140.4	U. S. 291 (No. 63)	A trace
32-10-5	102.1	Creole (No. 7)	14.7

*Micrograms per gram of sample.

†Used with the permission of Miller and Covington and taken from a paper published in volume 40 of the Proceedings of American Society for Horticultural Science.

From the data in Table III it is seen that the carotene content of sweet potatoes can be materially increased by breeding. It is to be noted that several of the seedlings contain in the neighborhood of 100 micrograms or more of carotene per gram of sample and one in particular with 151.5 micrograms per gram. These figures in some cases are twice as high as accompanying parent varieties.

The vitamin A requirement of man varies with age and activity. Lease (5) has figured out, on the basis of the carotene content of a good strain of Porto Rico Sweet Potato, that if one eats a potato weighing 150 grams two or three times a week, he will obtain all the vitamin A he needs for this period whether any is gotten from any other source or not. However, on the basis of recent work these figures are thought by some nutritionists to be too low. Since the soils of much of the south is adapted to fairly high yields of sweet potatoes, there is a present day challenge to utilize this crop to supply much of the vitamin A so vitally essential for our own good and for the good of our livestock.

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Residual Effects of Phosphorus on Irish Potatoes in South Alabama

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THE equivalent of approximately 10,000 tons of superphosphate is used annually on the commercial crop of Irish potatoes in South Alabama. A relatively small part of this is utilized by the plant and only that part found in the tubers is removed from the land. Studies at the Alabama Main Station on three different soils indicate that about 6 to 7 per cent of the phosphorus applied in a standard application of fertilizer is removed by the tuber with another 3 to 4 per cent utilized by the plant but returned to the land in foliage and stems. It may be seen, therefore, that about 93 per cent of the phosphorus applied remains on the land. It is known, however, that a large part of the phosphorus applied to crops soon becomes "fixed" by the soil and, therefore, not readily available to plants. Weiser (5) has given a rather extensive bibliography and a brief discussion of the factors affecting the rate and the amount of phosphorus fixation by soils, and this need not be reviewed here. The work of Scarseth and Chandler (2) has added to the available information on phosphorus losses by soil movements. The organic phosphorus returned to the soil in stems and foliage is mineralized as the vegetable matter decomposes; it is probable, however, that the phosphorus thus released is "fixed" about as fast as it is released.

The commercial potato crop in South Alabama receives about 1,500 pounds per acre of a fertilizer containing 10 per cent of phosphoric acid, or 150 pounds of P_2O_5 per acre (4). A yield of 150 bushels of potatoes would remove from the land only about 10 pounds of P_2O_5 , thus leaving (in the soil) about 140 pounds of the phosphorus applied to the crop. It is of much importance to both technical workers and growers to have some idea of the residual effect of the phosphorus which has been applied to the land in past years.

PROCEDURE

In 1931 an experiment was started at the Gulf Coast Substation to measure the carry-over or residual effects of phosphorus when applied at different rates to the same area for a period of years and to see how this carry-over might affect the amount of phosphorus needed in subsequent years for maximum yields. The rates consisted of 16, 12, 8, 4, and 0 per cent P_2O_5 on a 1500-pound-per-acre basis. Each of these rates was applied to a given plot for a period of 4 years, and the rates on the different plots then altered to permit during the second period each of the several rates of application to follow each rate used during the first period except for the 12 per cent rate. A sufficient number of plots of each rate was started during the first period to give after the change, triplicate plots of each altered rate during the second period. Field plots of 1/60 acre were used. The soil was a Norfolk sandy loam

potentially of high fertility but a soil having a high phosphorus deficiency. The plots were located on recently cleared land which had not received phosphorus before the experiment began and on which practically a complete failure of all truck crops has been experienced when no phosphorus was applied.

Available phosphorus in the soil was determined by the Truog method (3). The amount of phosphorus in plant tissue was determined by the Fiske and Subarrow method (1). Yields of potatoes were based on United States Standard grades. Soil samples for the determination of available phosphorus were obtained during December after fertilizer applications in the spring. Twelve borings were made on each plot and the soil composited for each sample.

The yield of plots receiving 16 per cent phosphoric acid each year during both periods was used to obtain a base yield or yield index for each year of the second period.

RESULTS

The yields of marketable potatoes for the first 4-year period and for the first, second, fourth, and sixth years after the rates were altered are given in Table I. The available phosphorus is given for the fourth and the seventh year following the change in the fertilizer rate.

TABLE I—AVAILABLE PHOSPHORUS AND THE ACTUAL AND RELATIVE YIELDS OF IRISH POTATOES ON PLOTS RECEIVING DIFFERENT RATES OF APPLICATION

P ₂ O ₅ Added*		Available Phosphorus**		Yields of Marketable Potatoes									
First 4 Years (Per Cent)	Second Period (Per Cent)	Dec 1938 P.P.M.—P	Dec 1941 P.P.M.—P	Bushels Per Acre					Per Cent of Base Yield†				
				1st 4 Years	1935	1936	1938	1940	1935	1936	1938	1940	
16	16	66	65	163	198	175	180	159	100	100	100	100	
16	8	34	41	163	201	204	152	127	102	117	84	80	
16	4	25	26	179	154	179	120	110	78	102	67	69	
16	0	22	17	150	156	118	63	45	79	67	35	28	
12	12	48	37	150	127	208	138	88	64	119	77	55	
8	16	62	45	144	190	212	167	132	96	121	93	83	
8	8	17	27	144	185	185	131	135	93	106	73	85	
8	4	15	17	144	128	144	102	80	65	82	57	50	
8	0	13	8	145	92	85	41	40	46	49	23	25	
4	16	50	53	94	210	196	176	111	106	112	98	70	
4	8	19	30	96	171	189	143	111	86	108	79	70	
4	4	12	10	105	163	147	80	100	82	84	44	63	
4	0	14	5	105	71	47	31	29	36	27	17	18	
0	16	32	42	1	192	184	167	151	97	105	93	95	
0	8	30	19	2	147	164	128	121	74	94	71	76	
0	0	5	4	1	14	21	15	9	7	12	8	6	

*Base rate of fertilizer application was 1500 pounds per acre of 6-X-9.

**Determined by the Truog method (3).

†Yield for each year of plots receiving 16 per cent phosphoric acid both periods.

Soils from plots which had received 16 per cent phosphoric acid or 240 pounds of P₂O₅ per acre during both periods gave 66 and 65 parts per million of available phosphorus when analyzed the fourth and seventh years of the second periods, respectively. In contrast, soils

from plots which had not received phosphorus at any time since clearing of the land, showed approximately 5 parts per million of phosphorus. Phosphorus in soils from plots which had received 16 per cent of phosphoric acid during the first period but none during the second period had dropped to 22 parts per million by the fourth year and to 17 parts per million by the seventh year after applications ceased. Soils in corresponding plots which had received 8 per cent phosphoric acid during the first period but none during the second period had dropped to 13 parts per million by the fourth year and to 8 parts per million by the seventh year. Soils which had received 4 per cent phosphoric acid during the first period had dropped to 14 parts per million by the fourth year and to 5 parts per million by the seventh year of the second period. Thus the available phosphorus in the plots which had received 4 per cent phosphoric acid for the first 4-year period had dropped to within 1 part per million of the amount in the untreated soil by the seventh year after applications were withheld. For the 8 and the 16 per cent rates the amounts were only about 3 parts per million and 13 parts per million, respectively, above the available phosphorus of the natural soil.

The available phosphorus in soils from plots receiving the various rates of application during the two periods shows a fairly close relationship to the rates of phosphorus applied when consideration is given to the years in which applications were made.

A study of the yield data reveals likewise a rather close relationship between the rates of phosphorus applied and yields obtained when due consideration is given to the years in which the yields were made and the years in which the rates were applied. There is also a rather high positive correlation between yields of potatoes in 1940 and the available phosphorus in 1941.

In addition to many technical aspects of this study there are certain practical aspects to the residual effects of phosphorus from different rates of application for the years which follow. A potato grower would like to know what amounts of phosphorus would be necessary for maximum yield where known amounts had been applied in past years. Plots which had received 16 per cent phosphoric acid during the first period but received none during the second period produced 79 per cent of a base yield (see footnote to Table I) the first year, 67 per cent the second year, 35 per cent the fourth year, and 28 per cent the sixth year after the last application of phosphorus was applied. The yields for corresponding years for the plots which had received 8 per cent phosphoric acid during the first period but received none during the second period were 46, 49, 23, and 25 per cent of the base yields. For the plots which had received 4 per cent phosphoric acid during the first period but received none during the second period the yields for the corresponding years were 36, 27, 17, and 18 per cent of the base yields. Plots receiving no phosphorus during either period have given yields during the second period ranging from 6 to 12 per cent of the base yield.

The yields of plots which received 16 per cent phosphoric acid during the second period were not noticeably affected any year of the

second period by the amount of phosphorus which had been applied during the first period. The average yields for the 4 years presented in Table I of the plots which received 16 per cent phosphoric acid during the second period following different rates during the first period were 178, 175, 174, and 174 bushels per acre for plots which had received 16, 8, 4, and 0 per cent application of phosphoric acid, respectively, during the first period.

It is obvious, therefore, that plots which receive 16 per cent or 240 pounds per acre of phosphoric acid receive enough phosphorus for potato yields not to be affected by the amount of past applications.

The rates of phosphorus applied during the first period did affect, however, to some extent the yields obtained during the second period of treatments where only 8 per cent phosphoric acid was used during the second period. The average yields for the four years of the plots which received 8 per cent phosphoric acid during the second period following different rates during the first period were 171, 159, 154, and 140 bushels per acre, respectively, on plots which received 16, 8, 4, and 0 per cent of phosphoric acid the first period.

There was a decrease in the average yield of plots which received 4 per cent phosphoric acid during the second period following 8 per cent phosphoric acid as compared to 16 per cent during the first period. This general relationship did not carry over when comparing yields for the 4 per cent rates during the second period following the 8 and 4 per cent applications during the first period.

There seem to be several generalizations which might be permitted in regard to the "carry-over" or residual effects of phosphorus on Irish potatoes in South Alabama on soils similar to the one used in this experiment. Some of these are as follows:

1. The effects of phosphorus applications are carried over for a considerable number of years, as indicated by crop yields and chemical analysis of the soil.

2. There is a general fixation of phosphorus by the soil which becomes more pronounced for each added year after applications end.

3. The available phosphorus as determined by chemical tests and by crop yields becomes quite low for all rates within four to seven years after applications end.

4. There are appreciable differences in the amounts of available phosphorus found in the soil which extend at least through the seventh year after the last applications of different rates of phosphorus have been made.

5. The amount of previous applications does not affect yields to any appreciable extent where high applications are being made during later years.

6. High applications over a 4-year period are of value to succeeding crops where low applications of phosphorus are being made during later years.

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Genes for Resistance to Powdery Mildew in *Cucumis Melo*

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CANTALOUPE powdery mildew (*Erysiphe cichoracearum* DC.) first attracted attention in the Imperial Valley of California in 1925. During succeeding years it was often present in epiphytotic proportions and in several seasons about one-half of the crop was a total loss. From 1926 to 1931 control by various fungicidal treatments and cultural practices was attempted but none proved adequate or economically feasible. Concurrently with these attempts at prevention, a cooperative breeding program involving the development of mildew-resistant varieties was initiated by the University of California and the United States Department of Agriculture.

Obviously the first step in a successful approach to the problem of breeding disease resistant varieties was the collection of material which would represent the entire range of variation of the species. Among several lots of seed imported from India in 1927 for this purpose, there appeared a number of plants which were immune or at least highly resistant to infection by the fungus. Through a series of crosses and backcrosses to commercial varieties, the gene for resistance was incorporated into a genotype with desirable horticultural and market qualities (1). The variety that was produced as a result of this work, Powdery Mildew Resistant Cantaloupe No. 45, seemed to be homozygous for resistance since continued inbreeding did not produce susceptible individuals. However, it is stated by Jagger and Scott (1) that when grown in the coastal districts of California the vines usually show some powdery mildew late in the growing season.

In 1938, powdery mildew symptoms appeared on vines in fields planted with the No. 45 variety in the Imperial Valley. Studies were immediately initiated to determine the nature of this "new" mildew. These studies produced convincing evidence of a new biologic race of the powdery mildew organism (2).

The appearance of a second biologic race of *Erysiphe cichoracearum* DC. made it necessary to reinvestigate our accumulated stocks of *Cucumis melo* L. for the purpose of detecting genes for resistance to race 2, if such were present. Employing a technique, described in another publication (3), considerable progress has been made with this work. We have evidence that genes for resistance to biologic race 2 are available from several sources.

The purpose of the present report is to point out one of the original sources of these genes and to suggest possible improvements in plant breeding techniques arising from this experience.

Jagger and Scott (1) indicate that a single dominant gene is responsible for the powdery mildew resistance of the No. 45 variety, although no figures are given to support this statement. Examination of the pedigree shows quite clearly that the gene for resistance originated with the material imported from India in 1927.

In a routine test for powdery mildew resistance, we have discovered a strain of cantaloupe highly resistant to both races 1 and 2 which stems from the same source as the No. 45 variety. Thus we have a rather unique situation, in that, in the development of the No. 45 variety, apparently only the gene for resistance to one race of mildew fungus was carried forward from the original source; but when a new race of the fungus became prevalent, this gene was not effective, and the No. 45 variety was definitely susceptible. In the sister line a full complement of genes for resistance to both races of the fungus was brought forward from the original source. This condition of course would not have been uncovered except for the advent of a second form of the pathogen.

If the above statements represent a true explanation of the observed phenomena, a determination of the comparative resistance of the original seed to race 2 of powdery mildew would be a critical test of the hypothesis. Unfortunately, it has been our experience that germination of cantaloupe seed 10 years old or over is very poor. Of the remaining original Indian material from which No. 45 was derived three seeds germinated, and only one survived to be tested. This plant was rated as susceptible to race 2 when the mildew readings were made 16 days after inoculation. The original seed from which our resistant cantaloupe was derived did not germinate. This left no alternative except to test for resistance at a higher level in the pedigree. For purposes of this test we chose a selection made in 1935. Field notes made at the time, indicate that of the five plants in the field trial all were free of mildew. In 1942, 32 plants of this selection were tested. All were rated as immune except for some slight necrosis on the leaves of a few plants.

These tests seem to substantiate the theory that in the development of the No. 45 variety only one gene for resistance was carried in the germplasm, while in the sister line, genes for resistance to both races of the pathogen must have been inherited from the original source.

We are not prepared at the present time to advance a full factorial explanation for resistance to powdery mildew (race 2) in cantaloupes. Preliminary data indicate that not less than two or three genes are involved. Complete dominance of susceptibility or immunity is lacking. The F_1 generation on our scale of rating susceptibility is approximately midway between the homozygous susceptible and immune plants.

The evidence from this experience seems to warrant mention of the following points:

1. The practice of carrying forward a number of lines from the original material is justified on the grounds that a few will contain a full complement of resistant genes. This is an important consideration and it appears to be one means of insuring the most efficient use of resistant material.

2. It would seem advisable to make collections of the pathogen from a wide range of localities in order to determine the reaction of desirable material to as many biotypes of the parasite as possible.

3. It demonstrates the practical importance of obtaining and main-

taining collections of material from areas in which the host species is endemic. Vavilov (4) has developed the theoretical background for this practice, and the evidence from our experience with *Cucumis melo* adds support to his theory.

4. The importance of rigorous testing of the material both in the greenhouse and in the field cannot be over emphasized. The plant breeder seeking to develop disease-resistant varieties of crop plants is faced with the problem of variation in two organisms, the host and parasite. This adds tremendous complications to the task, and unless adequate techniques are available for testing resistance, progress is slow and uncertain.

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Natural Crossing in Tomatoes as Related to Distance and Direction¹

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ALTHOUGH the amount of natural crossing in tomatoes is known to be low as compared to certain other crops, it is usually sufficient to cause serious contamination in breeding and seed growing work. It is generally considered to be the result of insect pollenizers since the pollen is not carried by wind. Lesley (1) reported 4.9 per cent cross-fertilization for the Magnus variety and only 0.59 per cent for Dwarf Champion. He explained that the difference might be due to differences in floral structure. In order to determine the effects of distance between plantings of different varieties and direction of prevailing winds upon the percentage of natural crossing, tests were conducted at Charleston, South Carolina and at St. Paul, Minnesota. The plan was identical at the two locations except that the rows were planted east and west at St. Paul and north and south at Charleston.

Each test was well isolated and consisted of a block of 16 plants of the Pritchard variety with plants spaced 6 by 6 feet apart. The block was four plants long and four plants wide. The rows were extended 12 plants on each of two sides of the block of 16 Pritchard plants with a strain that was homozygous for potato leaf and for the absence of anthocyanin color in the stems. These two characters are recessive and do not appear in the first generation when crossed with the homozygous dominant. Potato leaf versus normal can be distinguished as soon as the plant forms true leaves, and the presence or absence of color in the stem can be determined as soon as the seedlings emerge. Since the Pritchard variety is homozygous for both the dominant alleles of the characters, the percentage of natural crossing in the young seedlings grown from seed of the recessive plants was readily shown.

Seed for testing the individual plant progenies were taken from six or more fruits of each of the 96 recessive plants at both locations. Individual plant progenies were grown until true leaves developed, at which time the number of seedlings resulting from cross pollinated seed was determined.

The data obtained from the plants grown at St. Paul are summarized in Table I. Excepting six progenies all individual plants produced more than 100 seedlings. The numbers for the six were 0, 18, 78, 69, 83, and 69. Other than those with 0 and 18 the populations were considered of adequate size. The amount of crossing was often quite variable between the four plants at a given distance. The most extreme

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variation was on the plants adjacent to the dominants on the east side where at one extreme was a progeny of 154 plants which contained eight hybrids or a crossing percentage of 5.2, and at the other extreme was a progeny of 145 plants which had no hybrids in it. As shown in Table I the mean for the four plants was 1.98 per cent. The largest amount of crossing obtained on any plant in the test was 5.2 per cent, but numerous plants produced progenies with no hybrids.

TABLE I—PERCENTAGE OF NATURAL CROSSING AS DETERMINED BY THE LEAF TYPE AND STEM COLOR OF PROGENIES FROM INDIVIDUAL TOMATO PLANTS RECESSIVE FOR THESE CHARACTERS GROWN AT 12 SUCCESSIVE 6 FOOT INTERVALS (ROWS) FROM THE SOURCE OF FOREIGN POLLEN AT ST. PAUL, MINNESOTA

Plants													Row Mean
<i>East</i>													
Source of foreign pollen	1.97	0.00	0.00	0.65	0.00	0.00	1.42	0.00	0.00	0.00	0.00	0.00	0.34
	5.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
	0.75	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
	No seed	0.71	0.35	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
Mean (East)	1.98	0.00	0.18	0.41	0.00	0.11	0.36	0.00	0.00	0.00	0.00	0.00	0.25
<i>West</i>													
Source of foreign pollen	0.51	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.15
	0.53	0.00	0.75	0.00	0.00	0.92	0.00	3.87	0.93	0.00	0.00	0.00	0.58
	3.29	0.84	0.43	0.33	0.50	0.00	0.00	0.00	0.00	1.79	0.00	0.00	0.60
	0.86	2.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27
Mean (West)	1.30	0.31	0.44	0.08	0.13	0.23	0.00	0.97	0.23	0.45	0.15	0.00	0.36
Mean, East and West	1.64	0.18	0.31	0.25	0.06	0.17	0.18	0.48	0.12	0.22	0.09	0.04	0.31

It is evident that increasing the distance by 6 feet row intervals between plants reduced the amount of crossing. There was none on the east beyond the 42-foot interval and on the west there were only four plants beyond this distance that produced crossed seed. These occurred at four different distances. It would appear that under these conditions very little if any crossing may be expected beyond an interval of 12 or 15 rows. The mean for the east is 0.25 per cent and for the west it is 0.36. Both percentages are low but the difference is 44 per cent of the smaller mean or 35 per cent of the mean of the experiment and may have some association with exposure, wind direction or other conditions.

The prevailing winds at St. Paul are from west to east, and it is of interest that there was more crossing and at a greater distance on the west than on the east side. A possible factor was a windbreak of low trees located on the west side of the planting, about 100 feet from the tomato plants. Conditions may have been such that insects were encouraged to work in that direction.

At Charleston, South Carolina, the test was identical with that at St. Paul except that rows extended from north to south; Table II shows the records on each progeny. These figures were obtained from random samples of 100 seedlings per progeny. The total amount of crossing was slightly less than at St. Paul, and the maximum percentage of crossing observed on any one plant was 5 per cent on a plant to the north and three plants removed from the block of Pritchard

TABLE II—PERCENTAGE OF NATURAL CROSSING AS DETERMINED BY THE LEAF TYPE AND STEM COLOR OF PROGENIES FROM INDIVIDUAL TOMATO PLANTS RECESSIVE FOR THESE CHARACTERS GROWN AT 12 SUCCESSIVE 6 FOOT INTERVALS (ROWS) FROM THE SOURCE OF FOREIGN POLLEN AT CHARLESTON, SOUTH CAROLINA

Plants													Row Mean
<i>North</i>													
Source of foreign pollen	0	0	1	0	0	0	0	1	0	0	0	0	0.17
	2	0	0	0	2	0	1	0	0	0	0	0	0.42
	3	1	0	0	0	0	0	1	0	0	0	0	0.42
	0	1	5	0	0	0	0	0	0	0	0	0	0.50
Mean (North).....	1.25	0.50	1.50	0	0.50	0	0.30	0	0.50	0	0	0	0.38
<i>South</i>													
Source of foreign pollen	2	3	0	0	1	1	0	0	0	0	0	0	0.58
	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	1	0	3	0	0	0	0	0	0	0	0	0	0.33
	1	0	0	0	0	0	0	0	0	0	0	0	0.08
Mean (South).....	1.0	0.80	0.80	0	0.30	0.30	0	0	0	0	0	0	0.25
Mean, North and South.....	1.13	0.63	1.13	0	0.38	0.13	0.13	0	0.25	0	0	0	0.31

plants. There were many plants which gave no crosses.

At Charleston the prevailing winds are from the south or southwest, and there was more crossing and at a greater distance on the north side of the block. It is possible that in this case the insects affecting pollination may have taken the path of least resistance and worked from plant to plant downwind. The respective percentages of crossing for plants on the north and south are 0.38 and 0.25. The difference is slightly greater than 50 per cent of the smaller mean and despite the variation of the data gives an additional suggestion that crossing percentage may not be the same in all directions.

To illustrate the general relationship of distance to percentage crossing the data from both tests were combined as means for each of the distances. Fig. 1 shows diagrammatically the relation of percentage crossing to distance in number of rows. The curve quite definitely suggests a logarithmic relationship between the two factors although certain means depart somewhat from the theoretical logarithmic values. It is possible that a greater number of observations might tend to eliminate some of the disagreement and provide a more regular curve. The relation between the means and distance has been tested by both linear and

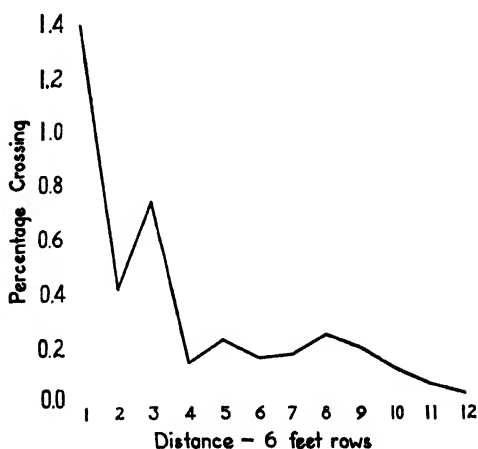


FIG. 1. The percentages of natural crossing in tomatoes in relation to distance in 6 foot row intervals.

nonlinear regression. The former gave a correlation coefficient of $-.698$. By replacing the actual percentages of crossing with their respective logarithms the correlation coefficient was increased to $-.846$, with the regression coefficient of logarithm of crossing on distance being -0.128 . Obviously this higher correlation coefficient suggests that the relationship may not be linear.

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Fruit Set and Development From Pollinated Tomato Flowers Treated with Indolebutyric Acid

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THE writer has recently shown that indolebutyric acid increases the set of pollinated tomato flowers and the resulting size of fruits (1). The extent of the improvement seemed to depend upon the amount of fertilization and embryonic development occurring previously or simultaneously. Faulty pollination is frequently responsible for unsatisfactory sets as well as for fruits deficient in parenchymatous tissue within the locules. Such fruits are produced during the short days of low light intensity which occur in the North during January to March. Unfilled locules result in hollow cavities or the locular walls may be contiguous, resulting in a meaty solid fruit, deficient in juice.

The above experimental work was carried out with potted tomato plants and with plants grown in a soil bed in the greenhouse of the Experiment Station at Wooster. However, in order to obtain data from plants grown under the environmental conditions of commercial greenhouses, later work reported herein was located in two such houses in northern Ohio. The work was designed to determine the extent to which the set and development of fruit could be improved by applications of indolebutyric acid to flowers which had already been subjected to the procedure employed by the grower to effect pollination.

TREATMENT OF THE PLANTS

The plants (Globe variety) were located in the Cleveland district. They had been bedded in the first house (Heinrichs) in January and in the second house (Hoag) in February. The plants employed were a portion of a range, two rows being selected in each house, the treated being alternated in the row with the untreated. Only the flowers of the first two clusters were involved in the experiment. The flower clusters were shaken once or twice daily by an electric vibrating device to effect pollination. All flowers were in full bloom at least 3 days before treatment; on the day of treatment all flowers were treated which had been tagged as open at the previous treatment (3 days previously) and all flowers which were open and untagged were tagged at this time for treatment the fourth day following. In this way all flowers had been at anthesis at least 3 days before the styles were severed and the flowers treated with indolebutyric acid in lanolin emulsion or in lanolin paste (both of 0.3 per cent concentration). This interval of 3 days was allowed for growth of pollen tubes through the styles of the treated flowers, thus not interfering appreciably with seed formation in the resulting fruits. The period of treatment in the first house was from February 24 to March 29; in the second house from March 18 to April 15.

PRESENTATION OF THE RESULTS

The data on the percentage of flowers setting fruit are presented in

Table I. There was a very marked increase in the fruit set in both houses, particularly in the earliest flowers to reach anthesis. For example, in greenhouse 1 (Heinrichs) 97 per cent of the first flowers of cluster 1 and 100 per cent of those of cluster 2 set fruit, as compared with 70 and 83 per cent respectively of the pollinated but untreated flowers. This increased set of treated flowers persisted through the sixth flower of the first cluster in greenhouse 1 and through the eighth flower of the first cluster in greenhouse 2. In the second cluster of

TABLE I.—EFFECT OF TREATING POLLINATED FLOWERS WITH LANOLIN EMULSION AND PASTE CONTAINING INDOLEBUTYRIC ACID (1941)

Flower Order	Greenhouse 1 (Heinrichs)				Greenhouse 2 (Hoag)			
	Treated Flowers		Untreated Flowers		Treated Flowers		Untreated Flowers	
	Number of Flowers	Per Cent Set	Number of Flowers	Per Cent Set	Number of Flowers	Per Cent Set	Number of Flowers	Per Cent Set
<i>Cluster 1</i>								
1.....	124	96.8 E*	153	69.9	127	100.0	124	72.6
2.....	26	96.2 P**	153	69.9	127	100.0	124	72.6
3.....	113	97.3 E	152	77.6	127	99.2	124	84.7
4.....	41	90.2 P	152	77.6	127	99.2	124	84.7
5.....	111	91.0 E	152	82.2	125	99.2	124	88.7
6.....	41	82.9 P	152	82.2	125	99.2	124	88.7
7.....	100	85.0 E	133	74.4	110	91.8	112	81.3
8.....	15	60.0 P	133	74.4	110	91.8	112	81.3
9.....	61	54.1 E	101	46.5	84	60.7	91	56.0
10.....	8	62.5 P	101	46.5	84	60.7	91	56.0
Total.....	26	42.3 E	48	20.8	56	37.5	64	28.1
1.....	10	30.3 E	15	33.3	27	40.7	44	20.5
2.....	6	33.3 E	6	16.7	14	35.7	24	16.7
3.....	3	0.0 E	3	0.0	11	0.0	12	25.0
4.....	3	0.0 E	3	0.0	11	0.0	12	25.0
5.....	3	0.0 E	3	0.0	11	0.0	12	25.0
6.....	3	0.0 E	3	0.0	11	0.0	12	25.0
7.....	3	0.0 E	3	0.0	11	0.0	12	25.0
8.....	3	0.0 E	3	0.0	11	0.0	12	25.0
9.....	3	0.0 E	3	0.0	11	0.0	12	25.0
10.....	3	0.0 E	3	0.0	11	0.0	12	25.0
Total.....	554	83.9 E	784	67.0	689	82.3	726	66.2
	132	83.3 P						
<i>Cluster 2</i>								
1.....	139	100.0 E	156	83.3	122	95.9	124	81.5
2.....	16	87.5 P	156	83.3	122	95.9	124	81.5
3.....	116	95.7 E	156	85.3	115	89.6	124	87.9
4.....	36	91.7 P	156	85.3	115	89.6	124	87.9
5.....	98	89.8 E	156	80.8	93	89.2	124	81.5
6.....	56	83.9 P	156	80.8	93	89.2	124	81.5
7.....	101	84.2 E	147	71.4	107	71.0	120	75.8
8.....	40	67.5 P	147	71.4	107	71.0	120	75.8
9.....	95	55.8 E	130	60.0	88	30.7	108	50.0
10.....	34	47.1 P	130	60.0	88	30.7	108	50.0
Total.....	77	37.7 E	98	41.8	55	25.5	86	30.2
1.....	16	37.5 P	98	41.8	55	25.5	86	30.2
2.....	44	27.3 E	61	37.7	29	13.8	60	11.7
3.....	11	63.6 P	61	37.7	29	13.8	60	11.7
4.....	30	23.3 E	37	16.2	13	0.0	28	7.1
5.....	5	20.0 P	37	16.2	13	0.0	28	7.1
6.....	22	22.7 E	25	8.0	7	14.3	16	0.0
7.....	12	16.7 E	13	15.4	4	0.0	8	0.0
8.....	12	16.7 E	13	15.4	4	0.0	8	0.0
9.....	12	16.7 E	13	15.4	4	0.0	8	0.0
10.....	12	16.7 E	13	15.4	4	0.0	8	0.0
Total.....	734	72.3 E	979	66.0	633	67.3	798	61.5
	214	70.6 P						

*E = treatment with lanolin emulsion.

**P = treatment with lanolin paste.

greenhouse 1 the greater set persisted through the fourth cluster, but in the second greenhouse only through the first flower. This result definitely indicates that the extent of the improvement in set brought about by the treatment depends upon the effectiveness of pollination

and fertilization since, as the season advances, the pollen is more readily distributed, a greater proportion is viable, more pollen tubes reach the ovary and more seeds are produced. Since this result occurs normally at this period (late March through April) the artificial stimulus obviously shows a smaller improvement.

Indolebutyric acid in the lanolin emulsion produced a slightly larger fruit set and somewhat more rapid acceleration of fruit development than in lanolin paste. This result has previously been reported (1). Where the emulsion can be used, it is superior to the paste in several other respects as well. The proportion of flowers setting fruit both from treated and untreated flowers was considerably less in the last flowers of the cluster to open. This undoubtedly is due to the intense competition between fruits (and flowers) for food materials and it is to be noted that the treatment with indolebutyric acid could only

TABLE II—COMPARATIVE WEIGHT AND NUMBER OF HARVESTED FRUITS FROM TREATED AND UNTREATED FLOWERS

Plants Involved	Total Number Fruits Harvested	Average Number Fruits Harvested Per Plant	Average Weight Per Fruit (Grams)
<i>Greenhouse 1 (Heinrichs)</i>			
Treated, 153 plants.....	1,315	8.6	181
Untreated, 154 plants.....	1,306	8.5	155
<i>Greenhouse 2 (Hoag)</i>			
Treated, 127 plants.....	1,085	8.5	170
Untreated, 124 plants.....	1,285	10.4	151

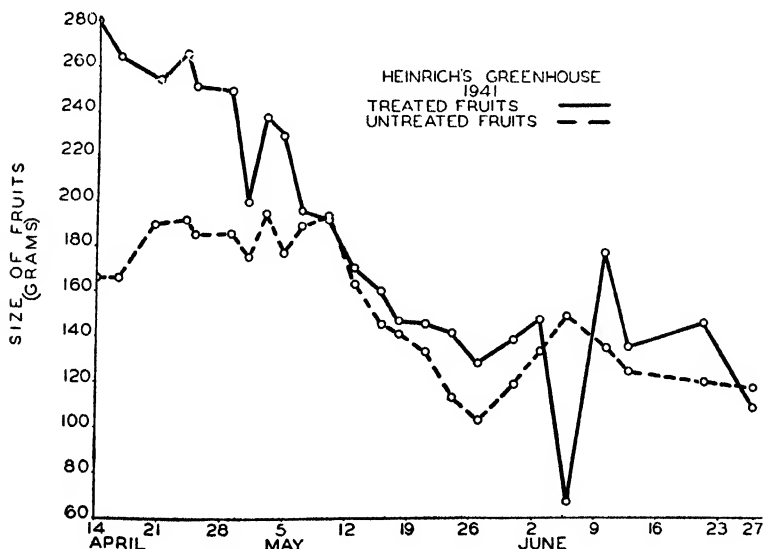


FIG. 1. Comparative weight of fruits from flowers treated with indolebutyric acid and those untreated, Heinrich's greenhouse, 1941. All flowers were jarred with the electric vibrator to effect pollination.

within narrow limits improve the set in the face of this severe competition.

Even more outstanding differences were obtained in fruit weight than in fruit set as indicated by the data in Table II and by Figs. 1 and 2. The treated fruits in both houses weighed 11 to 12 per cent

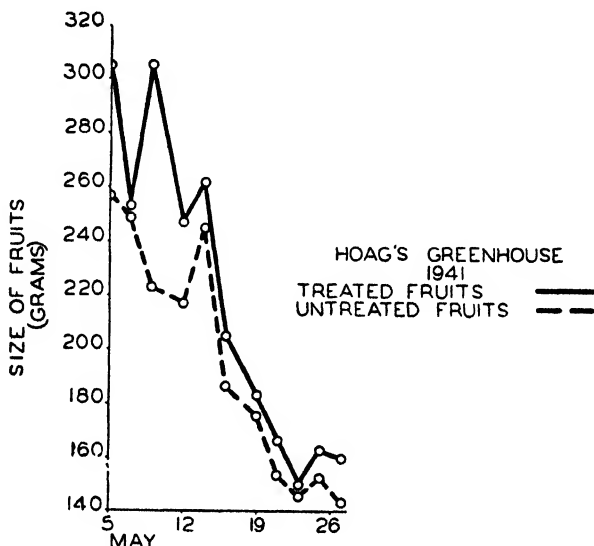


FIG. 2. Comparative weight of fruits from flowers treated with indolebutyric acid and from those untreated, Hoag's greenhouse, 1941. All flowers were jarred with the electric vibrator to effect pollination.

more than those from untreated flowers. As indicated by the graphs the differences in weight were particularly outstanding during the first few weeks of harvesting. During the first 2 weeks in greenhouse 1, the fruits from the treated flowers averaged a 35 per cent increase in weight over those from untreated flowers. The differences in house 2 during this period were also outstanding but naturally not as pronounced as in house 1, since the amount of fertilization and consequent seed development, a factor associated with fruit size, was greater in the fruits of greenhouse 2 as a result of more effective pollination and fertilization when the days were longer and the light supply more favorable.

The greater number of fruits from the untreated plants in greenhouse 2 was due to the fact that treatment was discontinued on the treated plants before the second cluster had finished blooming, whereas on the untreated plants all fruits on this cluster were harvested, counted, and weighed by the grower.

Another favorable result was that no fruits from treated flowers in either cluster developed blossom-end rot. As previously indicated, the lanolin emulsion favors development of this disorder when environmental conditions are contributory.

The treated flowers showed a remarkable acceleration of development immediately following treatment. Due to the fact that many of the first flowers of the first cluster in greenhouse 1 had elongated, flattened styles, some roughened or "cat-faced" fruits developed on both the untreated and treated plants. It is not known at present whether the rapid growth accentuates this condition on the fruits from treated flowers.

An even more outstanding difference, however, between the fruits from the treated and untreated flowers was the development of the parenchymatous tissue within the locules. Almost invariably the fruits from untreated flowers of the first cluster (and often of the second) in greenhouse 1 contained seeds in a few locules only; in some instances seeds were missing. Consequently, there was an uneven development of gelatinous pulp. On the other hand, the fruits from treated flowers almost invariably showed the locules well filled with this desirable material. In this respect the indolebutyric acid was particularly valuable in view of the fact that many of the ovaries of the flowers were often misshapen, a condition usually followed by less parenchymatous tissue within the locules as a result of insufficient fertilization.

The results presented herein thus indicate that indolebutyric acid may be employed under the conditions prevalent in commercial greenhouses during the period from February to April with very favorable results upon fruit set and development.

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The Relationship of Stem Diameter to the Number of Flowers, Number of Fruits, and Weight of Fruit per Cluster in Greenhouse Tomatoes

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THE relationship between vegetative growth and flower and fruit production has been studied by many workers during recent years. The general conclusion that plants making moderately vigorous vegetative growth is most desirable for maximum flower and fruit production is well established. In growing such a crop as tomatoes in greenhouses where most of the environmental factors, except light, can be controlled, the application of this knowledge is of considerable importance. The vegetative vigor can be fairly well controlled by the proper use of fertilizers and water, temperature control, and so on. If some simple measurement could be used as an indication of vegetative vigor, and the size range is known within which the highest fruit production is secured, it is believed that the problem of proper handling would be simplified.

To study such a possibility the diameter of the stem was taken as a measure of vegetative growth. Diameter measurements were taken midway between the peduncle and the node immediately below it. This measurement was made at the time the second flower of the cluster opened. The number of flower buds was counted at the same time. The number and weight of fruits per cluster was recorded as the fruit matured. These data were secured for six to nine clusters per plant on ten plants of each of seven varieties, for three crops. Only the data for three varieties of the spring crop in 1937 are summarized in this report.¹

No special attempt was made to vary the vigor of the plants as they were being grown for other experimental purposes too; however variations did occur which provided data for this study. Extreme conditions of vigor were not present as the crop was grown on a commercial basis. The crop was better than average in regards to production; plants averaged around 13 pounds of fruit each. The ranges in variation of the factors studied were: .5 to 1.7 centimeters for stem diameters, 1 to 11 for number of fruit, 14 to 49 ounces for weight of fruits, and 2 to 23 for number of flowers.

To investigate the relation between vegetative vigor and fruitfulness, correlations were determined between the stem diameter and number of flowers, number of fruits, and weight of fruit per cluster. The correlation coefficients found are presented in Table I. From these results it appears that the most consistently significant correlation is between the number of flowers per cluster and the diameter of the stem at the second cluster below. This would seem reasonable because at the time of rapid stem enlargement at a given point, the buds are developing for the cluster several nodes above. No significant cor-

¹A complete report will be published in the near future as a bulletin by the Oklahoma Agricultural Experiment Station.

TABLE I—CORRELATION COEFFICIENTS BETWEEN STEM DIAMETER AND NUMBER OF FLOWERS, NUMBER OF FRUITS, AND WEIGHT OF FRUIT PER CLUSTER OF GREENHOUSE TOMATOES

	Number of Flowers	Number of Fruits	Weight of Fruits
<i>Marglobe</i>			
Stem diameter adjacent to 2 clusters below.....	.566 ± .059*	.029 ± .106	.409 ± .087*
Stem diameter adjacent to 1 cluster below.....	.367 ± .069*	-.047 ± .095	.373 ± .065*
Stem diameter adjacent to cluster.....	.377 ± .064*	.174 ± .095	.378 ± .061*
Stem diameter adjacent to 1 cluster above.....	.....	.176 ± .074	.226 ± .072
Stem diameter adjacent to 2 clusters above.....	.....	.219 ± .077	.256 ± .075
<i>Michigan State</i>			
Stem diameter adjacent to 2 clusters below.....	.259 ± .082	.232 ± .083	.439 ± .071*
Stem diameter adjacent to 1 cluster below.....	.148 ± .080	.137 ± .080	.361 ± .071*
Stem diameter adjacent to cluster.....	.115 ± .074	.152 ± .074	.282 ± .069*
Stem diameter adjacent to 1 cluster above.....	.....	.142 ± .080	.295 ± .074*
Stem diameter adjacent to 2 clusters above.....	.....	.084 ± .087	.239 ± .083
<i>Lloyd Forcing</i>			
Stem diameter adjacent to 2 clusters below.....	.656 ± .049*	-.470 ± .069*	-.466 ± .069*
Stem diameter adjacent to 1 cluster below.....	.367 ± .069*	-.076 ± .082	-.432 ± .066*
Stem diameter adjacent to cluster.....	.129 ± .074	.392 ± .065*	.361 ± .066*
Stem diameter adjacent to 1 cluster above.....	.....	.350 ± .073†	.304 ± .069*
Stem diameter adjacent to 2 clusters above.....	.....	.176 ± .086	-.066 ± .088

*Significant at the one per cent level.

†Significant at the five per cent level.

relations between number of fruits and stem diameter were found with the varieties Marglobe and Michigan State. In Lloyd Forcing there was significant correlations between number of fruits and the stem diameters adjacent to the cluster, and the stem diameter one cluster above. Correlations of these factors were negative for stem diameters further above or below the cluster. The same relationship is found in this variety between weight of fruit and stem diameter. Significant negative correlations were secured with weight of fruit and stem diameters one cluster below and two clusters below. With Marglobe and Michigan State the best correlations were found between fruit weight and the stem diameter at the second cluster below. This is in direct contrast to the condition found with Lloyd Forcing.

The variation in varieties is difficult to understand. From the results with Marglobe and Michigan State it would appear logical to conclude that the food materials synthesized in the more luxuriant foliage associated with a greater stem diameter are translocated up the stem to higher clusters rather than moved downward. This, however, could not be the situation in Lloyd Forcing because of the high negative correlation between stem diameter and weight of fruits on clusters several nodes above. It may be that the other varieties on which data were secured will line up, along with these three analyzed, into two separate groups. The difference may be associated with the fact that Lloyd Forcing has an English forcing type heritage, as compared to the American type represented by Marglobe.

It is indicated by the results with the varieties Michigan State and Marglobe that conditions which favor the development of large stemmed plants are also favorable for flower and fruit development. Since the highest correlations were found between weight of fruit and the stem diameter at some distance below the clusters, it is considered that for

continued production, the maintenance of suitable conditions for the development of large stemmed plants is desirable. A reduction in vegetative vigor, which will occur after a few clusters of fruit have set unless proper fertilization and care are given, will be reflected by a reduction in fruit production on the clusters which develop after such reduction is apparent.

Further Studies on the Effect of Topping Young Tomato Plants on Fruit Set and Yield¹

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THIS paper reports the results of work done during the past season in an attempt to account for certain inconsistencies in the results of studies in progress from 1938 to 1940 inclusive, which were reported last year (1). Since the methods of plant-growing used in those experiments differed each year, either with respect to the spacing of the young plants or whether they were pot- or flat-grown, it seemed desirable to evaluate the influence which these factors might have had on the expression of the topping treatment.

The plants were grown in the University greenhouse and the field planting was made at the Horticulture Farm in Morgantown on a Tilsit silt loam. The Early Baltimore and Marvelous varieties were used to represent the early and late ripening types as in the past, and again the topping treatment consisted of pinching off the main stem of the young plants above the second leaf (node) about 2 weeks before the plants were to be set in the field.

On March 27 seedlings of both varieties were pricked off in flats at 2 by 2 inch and 4 by 4 inch spacings. An equal number were potted in 3-inch pots, half of which were placed as close as possible and the remaining half spaced so that the plants were 4 inches apart on the square. On April 23 they were transferred to the coldframe at the same spacings and half of each lot was topped. This resulted in eight equal sublots which were pot- or flat-grown but which varied in respect to variety, spacing, and the topping treatment. Fig. 1 shows representative Early Baltimore plants of each of these sublots on May 20 when they were set in the field. Since the treatment effects on the Marvelous plants were substantially the same a similar plate showing this variety is omitted.

In the field a factorial experiment of split-plot design, as described by Yates (2) and Brandt (3), was used since it offered possibilities of a precise conception of the interrelations of these factors. Emphasis was placed in descending order as follows: the topping treatment, plant spacing, variety, and method of plant growing. Since there were two levels of each factor under consideration, the number of combinations was 16.

The field planting consisted of four tiers or blocks of 16 single-row plots each 16 plants long. The plants were spaced 3 feet apart in the rows which were 6 feet apart. The treatments were randomized in each block. The harvest period began on July 7 and because of extended drought conditions ended earlier than usual on September 3. During this time record was made of both the number and the weight of fruits of the marketable and the total yields from each plot for the early (July 7 to 31 inclusive) as well as the entire producing season. The

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FIG. 1. Early Baltimore tomato plants, May 20, showing effect of treatments. Pot-grown (A) and flat-grown (C) normal (1 and 3) and topped (2 and 4) plants having been spaced two (1 and 2) and four (3 and 4) inches apart.

pickings occurred at frequent intervals. All fruits regardless of size were gathered if they were sufficiently colored to satisfy market demand. Those large enough to meet the requirements for the No. 1 grade were considered marketable. On September 12, the plants were stripped of all fruit in order to determine the treatment effect on total fruit set. The plant stand was incomplete only on two plots — one plant missing in each — for which corrections for full stand were made on the basis of the performance of the remaining plants of the plot.

Table I is intended to bring together the summarizations of the analyses which involve nine items of measurements and to indicate those factors or combinations of factors influencing the highest yields. For the sake of brevity as well as the fact that the purpose of this study was primarily to determine the effects of the considered factors alone and in combination, tables giving the means and conventional statistics are omitted.

TABLE I—GENERAL EVALUATION OF THE EFFECT OF THE TOPPING TREATMENT ON YOUNG TOMATO PLANTS AS INFLUENCED BY SPACING DISTANCE, SEASON OF VARIETY AND METHOD OF PLANT GROWING BASED ON THE SUMMARIZATION OF ANALYSES OF YIELDS FROM EXPERIMENTAL PLANTING AT MORGANTOWN, WEST VIRGINIA, 1941

Factors and Interactions	Early Yields (Jul 7 to 31 Inclusive)				Season's Yields		Jul 7 to Sep 3 Inclusive		Total Set
	No. 1 Fruits		All Fruits		No. 1 Fruits		All Fruits		Jul 7 to Sep 12
	Num- ber	Weight	Num- ber	Weight	Num- ber	Weight	Num- ber	Weight	Num- ber
Plant spacings.....	W†	W†	W†	W†	W	W	W*	W	W*
Varieties.....	B*	B	B*	B	B	B	B†	B	B†
Plant sources.....	P	P	P	P	P	P	P	P	P
Spacings X varieties.....	W-B	W-B	W-B	W-B	W-B	W-B	W-B	W-B	W-B
Spacings X sources.....	W-P*	W-P†	W-P*	W-P*	W-P	W-P	W-P	W-P	W-P
Sources X varieties.....	P-B	P-B	P-B	P-B	P-B	P-B	P-B	P-B	P-B
Sources X Spacings X Varieties.....	---	---	---	---	---	---	---	---	---
Treatments.....	N†	N*	N†	N†	T	T	N	N	N
Treatments X sources.....	N-P*	N-P†	N-P*	N-P†	T-P†	T-P	N-P*	N-P	N-P
Treatments X spacings.....	N-W	N-W†	N-W†	N-W*	T-W	T-W	N-W†	N-W†	N-W†
Treatments X varieties.....	N-B	N-B	N-B*	N-B	T-B	T-B	N-B	N-B	N-B
Treatments X spacings X varieties.....	---	---	---	---	---	---	---	---	---
Treatments X sources X spacings.....	---	---	---	---	---	---	---	---	T-P-W†
Treatments X sources X varieties.....	---	---	---	---	---	---	---	---	---

†Denotes significance at the 1 per cent level.

*Denotes significance at the 5 per cent level.

Treatment descriptions with symbols for the above table:

Source	Variety	Spacing	Treatment
Pot-grown (P) and Flat-grown (F)	Early Baltimore (B)	Close (C)	Normal (N)
		Wide (W)	Topped (T)
	Marvelous (M)	Close	Normal
		Wide	Topped

With respect to the early period it is evident that the plants which had been grown at the wider spacing yielded a significantly greater number and weight of both marketable and off-grade early fruit. Although the Early Baltimore variety outyielded the Marvelous variety, only the difference in number of fruits was of statistical significance. The pot-grown plants consistently yielded more than did the flat-grown plants, but in no instance was there significance. The interactions of these factors lend support to these findings and strongly suggest that, among these factors, the wide spacing exerted the greatest

influence on yield. The topping treatment is seen to have definitely curtailed early yields, and its interactions with the factors considered above further emphasize the effect on yields of the wide spacing and the potting of young plants. Variety differences were evidently small.

The influences exerted singly and in combination by these factors on the yields for the entire harvest period are in general similar to those for the early period. However, with a few exceptions, the yield responses were of no statistical significance. This could well be interpreted to indicate that the persistence of the effects of the factors under consideration decreased as the plants became older. Here again the Early Baltimore variety is seen to have produced significantly more fruits but evidently they were smaller since the yields by weight, although greater, were of little significance. It is also of interest to note that the topped plants tended to yield more No. 1's during the entire harvest period even though the normal plants surpassed them in early yields. This reversal in effect could easily have been the result of the check in growth caused by the topping treatment and could be expected to retard the peak of the early production. This explanation seems to be further substantiated both by the tendency of the normal plants to yield more fruits of all grades for the entire season and by the corroborating evidence shown in the interaction of the topping treatment with plant sources and spacings. It would seem in the last instance that the topping treatment also resulted in a retarded increase in fruit set since the final record of all the fruits set by the plants was not made until 9 days after the harvest period had ended.

The total fruit set was definitely greater on the Early Baltimore plants and on the plants grown at the wider spacings. Although the tendency for the normal plants to set heavier is evident, significance is obtained only with the wider spacing.

The results show the topping treatment to have reduced the early yields of both varieties, but as the season advanced, the yield differences decreased and lacked statistical significance. Both varieties apparently responded to treatment in the same manner. Also, those plants, whether pot- or flat-grown, reared at the wider spacing gave significantly larger yields. The general tendency for the pot-grown plants to yield more can be attributed in part to elimination of disturbance when they were set in the field, since it is doubtful that they were much affected by "pot-binding." These findings, together with the fact that differences obtained in the previous studies were generally small or inconsistent, suggest that the topping treatment may be practical as an emergency measure in holding young plants late in the season, particularly when the entire crop is to be marketed.

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Effect of Nutrient Root Media on Loss in Weight and Amount of Rot in Stored Tomatoes

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DURING 1939 and 1940, tomatoes were grown in nutrient solutions and soils in the Plant Nutrition greenhouses at Berkeley. After yield records had been obtained, the fruits were stored at Davis in controlled temperature rooms. The data obtained from these plants will be published in a series of articles the first of which, by Arnon and Hoagland (1), has already appeared and included a description of the experimental methods used in growing the plants. The present paper, comparing the storage qualities of tomatoes grown in different soils and nutrient solutions, is a part of this series.

LITERATURE

There is little literature bearing directly on the relation of the nutrient medium to the keeping quality of fruit. The characteristics measured would be influenced by loss of water from fruit, by respiration, and by factors affecting inoculation and the development of storage rots. Nutrition is apparently not a major factor affecting any of these processes.

Lanham (4) studied the effect of potash fertilizers on the "carrying" quality of tomatoes. By applying these fertilizers he increased the potash content of the fruit 22 per cent and 44 per cent, and that of the vegetative parts of the plant 48 per cent. He concludes, "Potash had no uniform effect on the length of time it took tomatoes in storage to ripen or decay". Potash also had no consistent effect on the time required for breaking the fruit by shaking (2), on the resistance of tomatoes to pressure, and (3) on the number of times the fruit could be dropped without cracking.

In Oklahoma, Cochran and Webster (3) found little correlation between chemical composition and handling (storage) qualities of green-wrap tomatoes grown on different fertilizer plots.

On a soil in which calcium was abundantly supplied and potassium inadequately supplied for maximum crop yields, Sayre, Kertesz, and Loconti (5) found that adding either calcium or potassium did not appreciably affect the calcium and potassium content or the firmness (drained weight) of canned tomatoes.

Walford (6) compared the respiration rate of fruits harvested at different times of the year and at different degrees of maturity. Fruits harvested during late spring and in the summer exhibited the lack of durability normal to this fruit, whereas those harvested in late autumn, winter, and early spring, if picked before turning red, passed into a stable state that prolonged their life at 12.5 degrees C.

Beadle (2) studied extensively the effect of position of tomatoes in the first two trusses (hands) on their respiration and growth. According to him, the fruits that ripen first have the highest sugar content and the highest respiratory intensity, besides occupying the first position on the truss.

METHODS

Tomato plants of Sutton's "Best of All" variety were grown in the following soils and nutrient media shown in Table I. The greenhouse soil was obtained from a greenhouse near Richmond. The Fresno soil was a Fresno fine sandy loam. Both of these soils were previously autoclaved at 20 pounds pressure. A soil obtained from Hanford was also used, but gave a low yield due to seepage or poor drainage. Tank 11 was located next to the tank with the Hanford soil.

TABLE I—ROOT MEDIA USED IN EXPERIMENTS

Summer 1939		Winter 1939-1940	
Tank	Medium: Soil or Nutrient Solution	Tank	Medium: Soil or Nutrient Solution
1	Greenhouse soil	5	High N, High P, High K
2	High N, High P, High K	6	High N, High P, Low K
3	Low N, High P, High K	7	High N, Low P, High K
4	Low N, High P, Low K	8	Low N, High P, High K
		9	Low N, High P, Low K
		10	Low N, Low P, High K
		11	Low N, High P, High K
		12	Greenhouse soil
		13	Fresno fine sandy loam
		14	Hanford soil
<i>High Series (parts per million)</i>			
NO ₃ = 1000-400			
PO ₄ = 200-100			
K = 400-200			
<i>Low Series (parts per million)</i>			
NO ₃ = 380-0			
PO ₄ = 20-0			
K = 40-0			

The tomatoes were picked at the usual greenhouse-ripe stage. They were stored at 77 degrees F to simulate retail market conditions, and at 55 degrees F to simulate the recommended storage temperature for ripe tomatoes (7). The individual fruits were weighed at weekly intervals, and the loss in weight was noted, together with the first visual signs of rot. After the appearance of rot no further weight

TABLE II—MAXIMUM PERCENTAGE DIFFERENCE BETWEEN NUTRIENT COMPOSITION OF LEAVES AND FRUIT GROWN IN DIFFERENT MEDIA

Plant Part	Media	Date	Extremes	Nitrogen			Phosphorus			Potassium		
				Tank No.	Parts Per Million	Per Cent Difference	Tank No.	Parts Per Million	Per Cent Difference	Tank No.	Parts Per Million	Per Cent Difference
Leaves	Nutrient solution	Jun 22, 1939	Minimum	2	5200	16	2	870	55	4	4520	19
			Maximum	3	6030		4	1345		3	5380	
Leaves	Soil	Jun 22, 1939		1	4480		1	414		1	4200	
Fruit	Nutrient solution	Jul 10, 1939	Minimum	3	1300	6	2	340	8	4	2570	5
			Maximum	2	1380		4	367		3	2710	
Fruit	Soil	Jul 10, 1939		1	1175		1	247		1	2975	
Leaves	Nutrient solution	Nov 17, 1940	Minimum	8	4050	15	10	525	79	9	4690	24
			Maximum	9	4660		9	940		7	5800	
Leaves	Soil*	Nov 17, 1940		12	4230		12	482		12	4940	
Fruit	Nutrient solution	Dec 27, 1940	Minimum	6	1115	26	7 & 11	287	29	6	2125	17
			Maximum	7	1400		6	369		5	2490	
Fruit	Soil*	Dec 27, 1940		12	1340		12	276		12	2905	

*Greenhouse soil—other analyses not available.

measurements were made. The data in the tables are the accumulated values after the first week. It was hoped to make a preliminary measure of quality by this means, but the individual tomatoes varied so greatly that no other quality measurements seemed justified.

The statistical values are calculated by means of the analysis of variance. There was a slight delay in transporting from Berkeley to Davis the fruits, for which the data are given in Table III and this likely accounts for increased rot and loss of the weight in the first week as compared with the data in Table IV.

RESULTS AND DISCUSSION

In interpreting these results, one must consider the physiological state of the plants in the different treatments. "High" and "low" as used here refer to relative differences in the concentrations of nutrients. Since all plants made average or better growth for greenhouse tomatoes, a low concentration in the sense used here might be regarded as barely adequate, whereas a high concentration may represent a surplus of the element in the nutrient solution. Analyses of the leaves and fruit indicated the physiological state of the plants, though not all the treatments are represented. These results are found in Table II. The extent of variability in composition is indicated by a comparison of the minimum and the maximum content of N, P, K of the leaves and fruit from the several nutrient solutions and the greenhouse soil. The minimum value was used as a base by which to calculate, for each element, the increased percentage of the maximum value. The fruit yields in Table IV indicate a somewhat greater variability in physiological state than do the fruit and leaf analyses (Table II).

The data obtained from storage are found in Tables III and IV. The 1939 data and degree of rotting in 1939-1940, gave few significant differences. There are significant differences for loss in weight in Table

TABLE III—THE PER CENT ROTTING AND LOSS OF WEIGHT OF STORED TOMATOES GROWN IN SOIL AND DIFFERENT NUTRIENT SOLUTIONS (1939)

Tank	Treatment	Number Fruits Stored	Per Cent Rotting (Weeks)				Per Cent Loss in Weight (Weeks)			
			1	2	3	4	1	2	3	4
55 Degrees F										
1	Greenhouse soil	68	0.0	5.9	6.3	31.2	1.8	2.7	3.7	7.2
2	High N, high P, high K	68	4.4	22.1	28.6	53.5	1.9	2.9	4.0	7.9
3	Low N, high P, high K	67	6.0	13.4	19.1	38.3	1.8	3.0	4.6	8.2
4	Low N, high P, low K	66	9.1	16.7	29.8	63.9	1.9	3.1	4.6	8.2
Difference re- quired for sig- nificance	}	Odds 19 to 1	14.6	22.6	32.3	23.5	0.4	0.5	0.6	0.5*
77 Degrees F										
1	Greenhouse soil	71	1.4	12.7	34.0	—	4.0	7.5	10.1	—
2	High N, high P, high K	70	0.0	37.2	55.2	—	5.2	8.0	10.8	—
3	Low N, high P, high K	65	7.7	24.6	37.0	—	4.3	7.1	10.7	—
4	Low N, high P, low K	67	6.0	26.9	48.9	—	3.3	5.5	10.6	—
Difference re- quired for sig- nificance	}	Odds 19 to 1	1.7*	28.2	16.9	—	0.6*	1.1	1.1	—

*Indicates F value is significant.

TABLE IV—THE PER CENT ROTTING AND LOSS OF WEIGHT OF STORED TOMATOES GROWN IN SOILS AND DIFFERENT NUTRIENT SOLUTIONS (1939-1940)

Tank	Treatment	Fruit (Pounds Per Plant)	Num-ber Fruits Stored	Per Cent Rotting (Weeks)				Per Cent Loss in Weight (Weeks)			
				1	2	3	4	1	2	3	4
55 Degrees F											
5	High N, high P, high K	7.6	102	0.0	3.9	7.8	19.1	2.7	4.8	6.8	8.4
6	High N, high P, low K	5.3	86	0.0	0.0	9.3	18.6	2.5	4.8	5.9	8.6
7	High N, low P, high K	6.2	100	0.0	3.0	8.0	23.0	2.9	4.7	6.7	8.1
8	Low N, high P, high K	6.2	120	0.0	5.8	11.7	25.0	2.1	4.4	5.3	7.5
9	Low N, high P, low K	6.0	109	0.0	0.0	1.8	19.3	3.4	5.7	8.1	10.1
10	Low N, low P, high K	5.4	89	0.0	0.0	7.9	16.9	3.4	5.7	7.6	9.8
11	Low N, high P, high K	4.9	114	0.0	0.0	5.3	14.0	3.4	5.5	7.0	8.9
12	Greenhouse soil	4.1	90	0.0	0.0	0.0	3.3	2.5	3.9	5.2	7.1
13	Fresno fine sandy loam	4.3	101	0.0	0.0	1.0	3.0	2.6	4.8	5.8	7.0
Difference required for significance—Odds 19 to 1				—	6.2	13.3	18.3*	0.6*	1.1*	1.3*	1.5*
77 Degrees F											
5	High N, high P, high K	—	87	0.0	4.6	11.4	35.6	4.7	8.5	12.1	14.4
6	High N, high P, low K	—	100	1.0	5.0	12.0	37.0	4.5	8.1	12.0	15.5
7	High N, low P, high K	—	115	0.0	6.1	20.9	41.8	4.6	8.2	11.7	14.7
8	Low N, high P, high K	—	114	1.7	6.1	12.3	45.6	4.7	8.3	11.7	14.9
9	Low N, high P, low K	—	97	0.0	4.1	15.9	42.1	5.1	9.3	12.9	13.6
10	Low N, low P, high K	—	113	0.0	0.0	9.8	32.7	5.3	9.4	12.3	15.4
11	Low N, high P, high K	—	90	0.0	1.1	2.2	7.8	5.5	8.5	11.3	14.6
12	Greenhouse soil	—	101	0.0	1.9	1.9	1.9	4.8	6.9	8.8	11.4
13	Fresno fine sandy loam	—	77	0.0	0.0	2.6	1.9	5.3	7.6	9.5	11.9
Difference required for significance—Odds 19 to 1				4.5	6.7	17.6	17.6	0.9*	0.4*	0.8*	0.4*

* Indicates F value is significant.

IV. These data indicate that the greenhouse and perhaps the Fresno sandy loam soils show less loss in weight than many of the nutrient solutions.

CONCLUSION

The root media of tomatoes in these experiments did not materially affect the amount of rot or loss in weight of the fruit.

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Vitamin, Protein, Calcium, Iron, and Calorie Yield of Vegetables Per Acre and Per Acre Man-Hour¹

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THE economic production of vegetables during the war emergency is an important consideration, especially under the present program of increased production and in view of a decreasing supply of agricultural labor, equipment, and materials. Since World War I some 50 different vegetable crops have become an increasingly important constituent of our national diet. At this time, possibly, some thought should be given to determining which crops can be most economically produced,² and which may be grown in a short period in case of a food emergency during the war or immediately after. The authors do not feel competent to discuss the dietary value of the crops listed in the accompanying tables. They serve only as a guide in showing the relative ease with which these food constituents may be provided. Taylor, Drummond, and Pyke (4) report the results of such tests with English gardens on the importance of vegetables in a wartime food-production program.

Nutritional value is a primary factor in selecting vegetables for a diet. From the standpoint of agricultural economy, however, the amounts of valuable food constituents produced per acre and per acre man-hour must be considered. Other items, including palatability and consumer preference, are less important under present conditions than the factors just mentioned. The known food constituents usually considered most valuable as commonly found in vegetables are proteins, calcium, iron, caloric content, and vitamins A, B₁, C, and G (riboflavin). All these except iron are listed by Bourne (1) as the dietary deficiencies that are likely to occur to a greater or lesser degree on the continent of Europe at the end of the war.

In this study an attempt has been made to evaluate the efficiency of 26 major vegetable crops on the basis of actual food constituents produced per acre and per acre man-hour. From existing information on composition, man-hour requirements, and average yields, the amounts of each food constituent per acre and per acre man-hour have been determined for each crop (Tables I, II, and III). These figures then provided a basis for computing efficiency ratings (Tables II and III).

The data in the tables were obtained for each crop through suitable calculations from total yields in pounds per acre, the per cent of edible portion, man-hours required per acre, the per cent of protein, calcium, and iron, the calories per pound, and the milligrams or micrograms of vitamins per 100 grams. These figures are necessarily based on average values, which appear to be the only basis available at present. Since most research has dealt with the composition of the more im-

¹The authors are indebted to Professor R. L. Adams, Dr. H. A. Jones and Professor Bessie B. Cook for suggestions and criticisms.

²Mr. A. M. Jongeneel of Walnut Grove, California, was responsible for bringing to the attention of the authors the importance of this subject under the present circumstances.

TABLE I—YIELD, MAN-HOURS PER ACRE, AND DAYS TO GROW CROP

Crops	Average Yield (Pounds Per Acre) ¹	Edible Portion (Pounds Per Acre) ²	Number Man-Hours Per Acre ³	Number Days to Grow Crop in Field to Complete Harvest ⁴
Asparagus.....	4,440	3,330	188	365
Beans, Lima.....	1,363	545	140	80
Beans, Snap (Bush).....	4,005	4,144	133	55
Beets, (Bunch).....	10,800	8,100	218	70
Broccoli (Bunch).....	7,340	3,450	176	150
Cabbage.....	13,680	9,987	111	90
Cantaloupe (muskmelon).....	9,780	5,868	195	160
Carrots (Bunch).....	19,440	17,496	243	80
Cauliflower.....	10,842	6,180	151	75
Celery.....	32,045	20,189	300	120
Corn, Sweet (Market).....	6,200	2,356	80	90
Cucumbers (Table).....	8,419	5,893	190	130
Lettuce (Head).....	9,058	6,250	109	80
Onions.....	19,840	18,650	239	110
Peas (Market).....	2,214	1,107	143	70
Pepper, Bell.....	6,928	5,820	144	150
Potato, Irish.....	15,180	12,751	130	120
Potatoes, Sweet.....	6,050	5,203	127	170
Radish (Bunch).....	12,000	5,880	273	30
Spinach (Table).....	11,729	9,618	117	50
Squash, Summer.....	9,750	9,457	147	125
Squash, Winter.....	17,000	12,580	58	180
Tomato (Table).....	7,514	7,364	177	160
Tomato (Canning).....	10,980	10,760	108	160
Turnip (Bunch).....	12,000	10,440	165	60
Watermelon.....	10,397	4,783	110	150

¹Yields obtained from 10-year averages found in Carl M. Schiller's Vegetable Crops in California 1931-1940. U. S. Department of Agriculture, Agricultural Marketing Service, Sacramento, California. Crops and Markets, United States Department of Agriculture, Vol. 18:293 (1941) and unpublished data for California.

²Chatfield, Charlotte and Georgian Adams. Proximate composition of American food materials. U. S. Dept. of Agriculture Circular 549. 1941.

³Data obtained from unpublished sources and from Farm Management Crop Manual by R. L. Adams, University of California Press, Berkeley (1941).

⁴Type books published by seed companies and Government agencies (General average for United States).

portant vegetables such as carrots or tomatoes, more figures are available for averaging their composition for these eight constituents. Therefore the data for these crops are likely to be more accurate than those for certain minor crops for which few analyses are available. The yield and man-hour data were obtained for California conditions but might vary some in other sections of the country. The man-hour requirements comprise all labor for culture and market preparation, including hauling to shipping point, market, or cannery.

The rating of the crops based on yield per acre of food constituents was obtained by two steps. First, the crops were arrayed in descending order in respect to their yields of each of the eight selected constituents. Within each array the crops were segregated into 10 groups. An index value of 1 was assigned to the highest group of each array, and consecutive increasing index values to the respective descending groups. The second step consisted in adding the index values for each crop to obtain its rating. A vegetable that was in group 1 in all eight constituents would have a rating of 8, while one in group 10 in all eight cases would have a rating of 80. The same procedure was followed in obtaining the rating for the amount of food produced per acre man-hour. The authors realize the imperfections of such a rating, since equal emphasis is given to each of the eight constituents. No

TABLE II—YIELD OF FOOD CONSTITUENTS PER ACRE,
WITH AN EFFICIENCY RATING

Crops ^a	Protein ^b (Pounds)	Calcium ^b (Pounds)	Iron ^b (Pounds)	Calories ^b (Thousands)	Vitamins ^c				Efficiency Rating ^d
					C (Grams)	B ¹ (Grams)	G (Grams)	A (Millions of International Units)	
Asparagus.....	73.3	0.6993	.0400	400	423	2.49	1.51	7.56	65 (19)
Beans, Lima.....	40.9	0.1689	.0125	324	62	0.74	0.62	1.24	79 (23)
Beans, Snap (Bush).....	99.5	2.6936	.0456	787	282	1.41	2.03	22.58	61 (17)
Beets, (Bunch).....	17.2	2.1060	.0729	1,256	146	2.20	3.49	3.68	58 (14)
Broccoli (Bunch).....	113.9	5.0370	.0483	587	1,411	1.41	5.48	94.0	46 (8)
Cabbage.....	139.8	4.4942	.0400	1,298	3,180	4.76	4.53	2.50	43 (7)
Cantaloupe (muskmelon).....	35.2	0.9976	.0235	734	798	1.54	2.00	37.30	63 (17)
Carrots (Bunch).....	210.0	7.3483	.1225	3,587	315	7.94	7.16	246.24	32 (2)
Cauliflower.....	148.3	1.5450	.0556	805	1,990	4.63	5.19	1.35	46 (8)
Celery.....	262.5	14.5361	.1413	2,019	646	3.21	3.94	2.56	37 (5)
Corn, Sweet (Market) ^e	87.2	0.2120	.0118	1,154	106	1.44	0.66	5.51	47 (9)
Cucumbers (Table).....	41.3	0.5893	.0177	383	212	2.41	4.01	0.88	68 (20)
Lettuce (Head).....	75.0	3.3750	.0688	531	400	2.50	4.83	10.93	55 (13)
Onions.....	261.1	5.9080	.0933	4,103	765	5.33	3.81	N ^f	33 (3)
Peas (Market).....	72.0	0.2435	.0210	476	101	1.93	1.13	5.78	71 (21)
Pepper, Bell.....	69.8	0.6402	.0233	786	3,171	0.66	1.03	132.11	58 (14)
Potato, Irish.....	255.0	1.6576	.1403	4,909	638	7.52	3.47	2.32	35 (4)
Potato, Sweet.....	93.7	1.7170	.0416	2,940	266	2.67	2.13	59.10	53 (12)
Radish (Bunch).....	70.6	2.1756	.0588	588	429	2.01	0.80	N	65 (19)
Spinach (Table).....	221.2	7.9829 ^g	.3270	1,058	1,443	5.40	15.28	873.31	21 (1)
Squash, Summer ^h	56.7	1.4187	.0378	804	132	2.06	3.48	128.80	59 (15)
Squash, Winter ⁱ	188.7	2.3902	.0755	2,516	176	2.74	4.63	171.34	42 (6)
Tomato (Table).....	73.6	.08100	.0442	773	766	3.11	1.67	28.42	60 (16)
Tomato (Canning).....	107.6	1.1836	.0646	1,130	1,119	4.54	2.44	41.50	49 (11)
Turnip (Bunch).....	114.8	5.3244	.0522	1,618	1,190	3.79	3.56	0.71	48 (10)
Watermelon.....	23.92	0.3348	.0096	670	153	0.76	0.76	1.63	78 (22)

^aAverage composition obtained from Henry C. Sherman, *Chemistry of Food and Nutrition* (1941) and Clara Mac Taylor, *Food Values in Shares and Weights* (1942). These books were used with the permission of the Macmillan Company Publishers, New York City.

^bEfficiency rating is a numerical evaluation of the combined eight constituents yield. Figures in parenthesis give order of rating.

^cApplicable only to yellow varieties, because of vitamin A content.

^dSherman¹ states that calcium is not nutritionally available, but spinach is used to illustrate the value of other greens such as kale, mustard, et cetera.

^eN indicates negligible.

^fChatfield, Charlotte and Georgian Adams. Proximate composition of American food materials. U. S. Dept. of Agriculture Circular 549. 1941.

method is known, however, whereby the relative values of these constituents can be more properly weighed. Possibly the only value of such a rating is that it indicates which crops are relatively high in a majority of these constituents, which crops are intermediate, and which are low in most of the constituents considered. In the grouping of the vegetables the groups with assigned values of 1 to 3 contained few crops and showed large group intervals, whereas the groups with assigned values of 7 to 10 contained relatively many crops and showed a small group interval.

In order to simplify Tables I, II, and III the vegetables were grouped according to the eight with the best rating and the eight with the poorest rating, both as to yield per acre and yield per acre man-hour (Table IV). In the high-yielding crops there are six vegetables common to both classifications based on yield per acre and yield per acre man-hour. There are seven vegetables common to both columns, of low-yielding crops. Spinach, winter squash, potatoes, carrots, and cabbage rank as the best vegetables if the ratings for yield per acre and per acre

TABLE III—YIELD OF FOOD CONSTITUENTS PER ACRE MAN-HOUR, WITH AN EFFICIENCY RATING

Crops ^a	Protein ^b (Pounds)	Calcium ^b (Pounds)	Iron ^b (Pounds)	Calories ^b (Thousands)	Vitamins ¹				Efficiency Rating ²
					C (Grams)	B ¹ (Grams)	G (Grams)	A (Millions of International Units)	
Asparagus.....	0.39	.0037	.00022	2.13	2.25	0.013	0.008	0.040	66 (15)
Beans, Lima.....	0.29	.0012	.00009	2.31	0.44	0.005	0.004	0.009	80 (19)
Beans, Snap (Bush).....	0.75	.0203	.00034	5.92	2.12	0.011	0.015	0.170	56 (10)
Beets, (Bunch).....	0.45	.0097	.00033	5.76	0.67	0.010	0.016	0.017	65 (14)
Broccoli (Bunch).....	0.65	.0283	.00027	3.34	8.02	0.008	0.031	0.534	52 (8)
Cabbage.....	1.26	.0405	.00036	11.69	2.86	0.043	0.041	0.023	40 (4)
Cantaloupe (muskmelon).....	0.18	.0051	.00012	3.76	4.09	0.008	0.010	0.191	66 (15)
Carrots (Bunch).....	0.86	.0302	.00050	14.76	1.30	0.033	0.030	1.013	40 (4)
Cauliflower.....	0.98	.0102	.00037	5.73	13.18	0.031	0.034	0.009	46 (5)
Celery.....	0.88	.0485	.00047	6.73	2.15	0.011	0.013	0.009	55 (9)
Corn, Sweet (Market) ³	1.09	.0027	.00015	14.42	1.32	0.018	0.008	0.069	60 (12)
Cucumbers (Table).....	0.22	.0031	.00009	2.02	1.12	0.013	0.021	0.005	72 (17)
Lettuce (Head).....	0.69	.0310	.00063	4.87	3.67	0.023	0.044	0.100	46 (5)
Onions.....	1.09	.0250	.00039	17.17	3.20	0.022	0.016	N ⁴	48 (6)
Peas (Market).....	0.50	.0017	.00015	3.33	0.71	0.013	0.008	0.040	68 (16)
Pepper, Bell.....	0.48	.0045	.00016	5.46	22.02	0.005	0.007	0.920	58 (11)
Potato, Irish.....	1.96	.0128	.00108	37.76	4.91	0.058	0.027	0.018	34 (3)
Potato, Sweet.....	0.74	.0135	.00033	23.15	2.09	0.021	0.017	0.470	48 (6)
Radish (Bunch).....	0.26	.0080	.00022	2.15	1.57	0.007	0.003	N	74 (18)
Spinach (Table).....	1.89	.0682 ⁵	.00279	9.04	12.32	0.047	0.131	7.464	18 (1)
Squash, Summer ³	0.39	.0097	.00026	5.47	0.90	0.014	0.024	0.886	58 (11)
Squash, Winter ³	3.25	.0412	.00130	34.38	3.03	0.047	0.080	2.950	20 (2)
Tomato (Table).....	0.42	.0046	.00025	4.37	4.33	0.018	0.009	0.161	61 (13)
Tomato (Canning).....	1.00	.0110	.00060	10.46	10.46	0.042	0.023	0.384	40 (4)
Turnip (Bunch).....	0.70	.0323	.00032	9.81	7.21	0.023	0.002	0.004	51 (7)
Watermelon.....	0.22	.0030	.00009	6.09	1.39	0.007	0.007	0.015	74 (18)

¹Average composition obtained from Henry C. Sherman, Chemistry of Food and Nutrition (1941) and Clara Mae Taylor, Food Values in Shares and Weights (1942). These books were used with the permission of the Macmillan Company Publishers, New York City.

²Efficiency rating is a numerical evaluation of the combined eight constituents yield. Figures in parenthesis give order of rating.

³Applicable only to yellow varieties, because of vitamin A content.

⁴Sherman¹ states that calcium is not nutritionally available, but spinach is used to illustrate the value of other greens such as kale, mustard, et cetera.

⁵N indicates negligible.

⁶Chatfield, Charlotte and Georgian Adams. Proximate composition of American food materials. U. S. Dept. of Agriculture Circular 549. 1941.

TABLE IV—GROUPING OF VEGETABLES BASED ON EFFICIENCY RATING OF PRODUCTION OF FOOD CONSTITUENTS PER ACRE AND PER ACRE MAN-HOUR

High Efficiency Rating Crops				Low Efficiency Rating Crops			
Rating Based on Yield Per Acre		Rating Based on Yield Per Acre Man-Hour		Rating Based on Yield Per Acre		Rating Based on Yield Per Acre Man-Hour	
Crop	Rating	Crop	Rating	Crop	Rating	Crop	Rating
Spinach	21	Spinach	18	Snap beans	61	Beets	65
Carrots	32	Winter squash	20	Cantaloupe	63	Asparagus	66
Onions	33	Irish potatoes	34	Asparagus	65	Cantaloupe	66
Irish potatoes	35	Cabbage	40	Radish	65	Market peas	68
Celery	37	Carrots	40	Cucumbers	68	Cucumber	72
Winter squash	42	Canning tomatoes	40	Market peas	71	Radish	74
Cabbage	43	Cauliflower	46	Watermelons	78	Watermelon	74
Broccoli	46	Lettuce	46	Lima beans	79	Lima beans	80
Cauliflower	46						

man-hour are combined. Spinach is grown in a short period of 50 days and so is desirable from the standpoint of the length of time it occupies the land. Kennedy (3), studying the relative economy of nutrients in

commonly used foods, found that spinach ranked high in most of the vitamins. Fincke and Sherman (2) have presented evidence that calcium is of low availability in spinach. Comparable figures are not available for mustard, kale, and other greens; but yields and labor would probably be similar to spinach, which was therefore used as an example of this group of crops. Cauliflower, carrots, and cabbage have a shorter growing period than potatoes and winter squash. In the group low in food value radish, peas, and lima beans have short growing periods. Peas for canning require much less labor than the market peas listed in the tables because they are harvested mechanically, which would improve their position as to yield per acre man-hour. Canning peas were not included in the tables, since they are a minor crop in California and since figures are not available for comparison. Further considerations are the number of man-hours and the amount of land required to produce the seed used in growing the crop. Potatoes would be at a disadvantage because 1/10 acre would be required to produce enough seed to plant an acre for food production. Small-seeded crops like spinach and carrots would require only 1/100 to 1/150 acre to grow the seed required for an acre.

The data presented herein indicate that certain vegetable crops possibly should be eliminated from production if, in the future, extreme economy of labor and equipment becomes necessary in vegetable production. In view of the present trend of decreasing supply of agricultural labor, some serious consideration should be given to this subject in order to assure the nation an adequate vegetable diet.

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Ascorbic Acid (Vitamin C) Content of Some Tomato Varieties and Species

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IN CONNECTION with the tomato breeding program at the United States Southeastern Regional Vegetable Breeding Laboratory, determinations of ascorbic acid content were made of field-grown tomatoes during the summer of 1941. Over 500 lines, including commercial varieties, foreign accessions, species, hybrids and selected lines were analyzed. The following represents a preliminary report of work now in progress.

Reviews of the literature have been made by MacLinn and Fellers (4), Fixsen and Roscoe (3), and others. In most of the reports commercial varieties ranged from about 15 to 40 milligrams of ascorbic acid per 100 grams of fresh weight. Currence pointed out (2) that caution should be used in recommending any one variety because of the variations to be expected under the wide range of conditions where it might be grown. In connection with tomatoes other than commercial varieties, Shivrina (7) stated that some of the wild and semi-cultivated forms had ascorbic acid values considerably higher than cultivated varieties. Since a wide variety of types was available in the present investigation, particular attention was paid to differences between these types and to differences in fruit size.

The ascorbic acid content of the tomatoes was determined by a method developed by Morell (6) which is a modification of photometric methods of Mindlin and Butler (5) and of Bessey (1). Fresh fruits were used in all cases and most lines were represented by eight samples, two from each of four randomized blocks. The data were reduced by analysis of variance.

RESULTS

No significant differences were found due to position in the field and slight but non-significant differences were found due to differences in ripeness, greener fruits having less ascorbic acid. Small but non-significant differences were found in successive pickings over a period of a month. The greatest variability appeared due to the differences between lines. The values obtained for 116 lines selected as representative of the whole are summarized in Table I.

The two small-fruited species, *Lycopersicon peruvianum* (L.) Mill. and *L. pimpinellifolium* (Jusl.) Mill. averaged the highest of any types examined. The former, a non-edible green-fruited species, consistently showed the highest values. Representatives of this species are P. I. No. 128,651 having 58.9 and P. I. No. 126,441 having 62.8 milligrams of ascorbic acid per 100 grams fresh weight of fruit. The latter species, the Red Currant tomato, included P. I. No. 127,830 with 35.9 and P. I. No. 127,833 with 47.0 milligrams per 100 grams.

The intermediate-sized lines (the 50 "P. I. Accessions" included in Table I) showed considerable variation in ascorbic acid content.

TABLE I—ASCORBIC ACID CONTENT OF TOMATOES
(1941, CHARLESTON, S. C.)

Identification	No. of Lines	Ascorbic Acid Content Per 100 Grams Fresh Weight Basis		Fruit Volume	
		Range* (Mg)	Mean and Standard Error (Mg)	Range (Cu In)	Mean and Standard Error (Cu In)
<i>Lycopersicon peruvianum</i> . . .	21	48.2-77.9	62.7 \pm 2.0	0.05- 0.3	0.15 \pm 0.01
<i>L. pimpinellifolium</i>	15	35.3-72.6	46.5 \pm 2.4	0.03- 0.19	0.08 \pm 0.007
P. I. Accessions†	50	10.2-50.5	20.6 \pm 0.9	0.5 - 2.9	1.7 \pm 0.1
Commercial varieties	30	11.2-21.6	15.2 \pm 0.7	1.5 - 12.8	5.9 \pm 0.8

*Range of averages for the various lines in each group.

†Exclusive of *L. peruvianum* and *L. pimpinellifolium*.

L. esculentum var. *cerasiforme* (Dun.) A. Gray and *L. esculentum* f. *pyriforme* (Dun.) C. H. Mull., the Cherry and Pear tomatoes respectively, were in this group. One of the latter, P. I. 128,639, averaged from two determinations 50.5 milligrams per 100 grams, the highest value for any *L. esculentum* type. Its fruit volume is approximately 2.3 cubic inches.

The commercial varieties showed the lowest values of any group but still had appreciable amounts of ascorbic acid. Since it seemed probable that there was a definite relationship between ascorbic acid content and fruit size (or some character associated with size such as surface area) correlations were calculated between ascorbic acid content and fruit volume, the latter approximated from measurements of polar and equatorial diameters. In each grouping in which there was a range of several volumes between the largest and smallest fruited lines, highly significant negative correlations were found between ascorbic acid content and volume. For example, in the 50 P. I. Accessions included in Table I, the correlation was -0.574 , the significant value at the 1-per cent point was -0.358 . Studies of ascorbic acid content of fruits of different sizes within varieties are being made.

Among the varieties examined were the 30 listed in Table II. Each mean value represents five to eight determinations. Although significant differences are found, no outstandingly high value was found for any of the widely grown varieties. The two highest varieties are both small-fruited. Summerset averaged in volume only about $1\frac{1}{2}$ cubic inches suggesting that it may be its small size which accounts for the high ascorbic acid content per unit of weight. The majority of the other varieties had fruits ranging from about 5 to 12 cubic inches in volume.

Some preliminary data on ascorbic acid content of hybrids revealed that in 11 crosses between small-fruited plants with high ascorbic acid content and large-fruited plants with low content, the first generation was intermediate in both size and ascorbic acid content. In six crosses between lines similar in both size and ascorbic acid content, the first generation did not differ significantly from the parental lines in either character. Single determinations on each of 166 second generation plants from a Red Currant tomato x Marglobe cross showed that the

TABLE II—ASCORBIC ACID CONTENT OF THIRTY TOMATO VARIETIES (1941, CHARLESTON, S. C.)

Variety	Source of Seed	Ascorbic Acid Content Per 100 Grams Fresh Weight Basis	No. of Determinations
		Mean* and Standard Error (Mg)	
Summerset.....	Texas A. E. S.	21.6±1.8	8
Vetomold.....	U. of Toronto	18.7±1.4	8
Early Baltimore.....	Associated	17.9±1.3	8
Rutgers.....	Stokes	17.7±1.3	7
Gulf State Market.....	La. A. E. S.	17.7±1.6	8
Pritchard.....	Associated	17.6±1.7	6
Bsary.....	Associated	17.3±2.4	6
Ponderosa.....	Kilgore	16.7±1.3	7
Marglobe (Strain 6).....	Stokes	16.4±1.2	6
San Marzano.....	Ferry-Morse	16.1±1.5	6
Riverside.....	Cal. A. E. S.	16.1±1.5	5
Pan American.....	U. S. D. A.	15.8±1.1	8
Mingold.....	Associated	15.7±1.1	8
Montgomery.....	Ala. A. E. S.	15.5±0.8	8
John Baer.....	Mich. A. E. S.	15.5±0.9	7
Indiana Marglobe.....	Associated	15.4±1.5	7
Redcap.....	N. Y. A. E. S.	15.3±1.7	6
Bred-Rite Marglobe.....	Kilgore	15.1±1.4	7
Stokesdale.....	Stokes	15.1±2.4	8
Norduke.....	U. S. D. A.	14.4±2.1	7
Marhio.....	Ohio A. E. S.	14.4±2.1	7
Early Shipper.....	Associated	13.8±2.0	7
Ny State.....	N. Y. A. E. S.	13.7±1.9	8
Earliana.....	Associated	13.0±0.4	8
Pearson.....	Associated	12.6±2.9	5
McGee.....	Ferry-Morse	11.9±1.4	8
Victor.....	Mich. A. E. S.	11.2±0.9	8
Bonny Best.....	U. S. D. A.	11.2±1.6	7

*Value for significant difference between means, 2.0.

ascorbic acid content in the F_2 ranged from about 9 to 42 milligrams per 100 grams fresh weight. The parental lines had 42 and 16 milligrams respectively. There was a significant negative correlation (-0.338) between fruit volume and ascorbic acid content in the second generation plants. The inheritance studies are to be continued.

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The Food Value of Mushrooms (*Agaricus campestris*)¹

By E. E. ANDERSON and C. R. FELLERS, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

DURING the past ten years the American mushroom industry has expanded rapidly and at this time is one of the important food industries. In 1940 alone, over forty million pounds of fresh mushrooms were produced in the United States. Pennsylvania produced approximately 55 per cent of the total crop while the remainder was grown in areas near Boston, Chicago, Cleveland, Kansas City, San Francisco, and along the Hudson River. The mushroom industry is also an important food industry in Canada. The *Agaricus campestris* mushroom is the one commonly cultivated for commercial purposes.

Until recently mushrooms were eaten almost entirely for their condimental value. The incorporation of mushrooms into gravies, sauces, soups, and other dishes added zest and flavor. However, recent scientific work has been carried out that would tend to place mushrooms in the average American diet not only on the basis of their already recognized flavor-enhancing properties but also because of certain definite food values the mushroom was found to possess.

A survey of the literature on the composition and nutritive properties of mushrooms presents a rather confused picture. This is due in part to the fact that many different types of mushrooms are reported under a common heading with little or no regard for variety. The nutritive properties and composition of different varieties of mushrooms do vary and often to a marked extent. Thus it is important to note that the investigations carried out at this laboratory were concerned entirely with the composition and nutritive properties of the commercially cultivated mushroom, *Agaricus campestris*, and not with any of the "wild" or foreign mushrooms.

The composition of fresh mushrooms is similar to that of many fresh vegetables and fruits as the following proximate analysis of *Agaricus campestris* indicates according to Anderson (1):

Water	89.50 per cent
Protein (Nx 6.25)	3.94 per cent
Fat (ether extract)	0.19 per cent
Extract matter	4.01 per cent
Fiber	1.09 per cent
Ash	1.26 per cent

An analysis of the ash of fresh mushrooms gave the following results:

Calcium	0.0024 per cent
Phosphorus	0.15 per cent
Potassium	0.50 per cent
Total iron	19.50 parts per million
Available iron	5.95 parts per million
Copper	1.35 parts per million

The protein present in mushrooms has long been a subject of much

¹Contribution No. 441, Massachusetts Agricultural Experiment Station.

discussion. From the extreme of being called the "vegetable beefsteak", the controversy has ranged to the opposite extreme where Chatfield and Adams (4) assigned a value of zero for the percentage of protein in mushrooms. Working with *Agaricus campestris*, Saltet (8) reported that the normal human being could digest 69 per cent of the nitrogen present in a sample of this mushroom. Skinner, Peterson, and Steenbock (10) similarly observed that albino rats could digest 71 per cent of the nitrogen in samples of *Agaricus campestris*. The results of our investigation of the quality of mushroom protein showed that when rats received mushrooms as a sole source of protein in their diet, they not only survived a 6 week test period but made a gain in weight equivalent to 30 per cent of that attained by rats on a casein positive control diet. When 20 per cent of the casein was replaced by mushroom protein, a growth gain was made equal to 84 per cent of that of the positive control group. On this basis mushroom protein would be termed by Sherman (9) a "partially incomplete" protein. Therefore although the application of the term "vegetable beefsteak" to mushroom is hardly appropriate, the protein present in mushrooms, being sufficiently available to support life and promote some growth, definitely warrants consideration as a source of nutritive value.

Although Sumi (13) found ergosterol to be present in several species of Japanese mushrooms in concentrations ranging up to 0.4 per cent of the dry weight, in the literature reviewed there were no figures found regarding the concentration of ergosterol in mushrooms of the *Agaricus campestris* variety. Preliminary investigation as to the effect of ultra-violet irradiation upon a dried powder prepared from *Agaricus campestris* mushrooms indicated that the vitamin D content was not materially increased.

The mineral content is somewhat higher for fresh mushrooms than it is in many fresh fruits and vegetables. From the analysis of the ash, it is evident that potassium and phosphorous salts are the main constituents of the ash. Copper and iron are present in relatively appreciable amounts. In the case of the iron, slightly less than one-third of the total iron is in the available form or in the condition readily utilizable by the human body. Calcium is not present in any significant amount.

Until quite recently little investigation was conducted on the vitamin content of mushrooms and even some of these results were contradictory. In an attempt to help clarify the vitamin status of mushrooms, chemical, microbiological, and animal assays were carried out on the *Agaricus campestris* mushroom. The results of these analyses (Table I) showed that *Agaricus campestris* is one of the best plant sources of several members of the vitamin B complex. Mushrooms were found to constitute an excellent plant source of riboflavin and nicotinic acid and a good source of pantothenic acid. They were also found to contain appreciable amounts of thiamin (vitamin B₁), ascorbic acid, and vitamin K. A prepared serving of a 100 gram portion of fresh mushrooms would provide approximately one-fifth of the adult daily requirement of riboflavin and over one-quarter of the adult daily

TABLE I—VITAMIN CONTENT OF FRESH MUSHROOMS PER 100 GRAMS

Material	Unit of Measure	Amount	Method Used
Vitamin A.....	International Units	none	U. S. Pharmacopoeia XI (15)
Vitamin B.....	Milligrams	0.12	Research Corp. Committee on the thiochrome method (7)
Vitamin B.....	Milligrams	0.52	Snell and Strong (11)
Vitamin C.....	Milligrams	8.60	Tillmans, Hirsch, and Hirsch (14)
Vitamin D.....	_____	none	A. O. A. C. (3)
Vitamin E.....	_____	none	Evans, <i>et al.</i> (5)
Vitamin K.....	_____	++	Ansbacher (2)
Nicotinic acid....	Milligrams	5.85	Snell and Wright (12)
Pantothenic acid	Milligrams	2.38	Pennington, <i>et al.</i> (6)

requirement of nicotinic acid. These adult daily standards are those suggested by the Committee on Food and Nutrition, National Research Council, May, 1941. Little or none of the fat soluble vitamins A, D, and E were found to be present in *Agaricus campestris*.

SUMMARY

The results of the findings of this laboratory help assure a place in the national dietary for the commercially cultivated mushroom on the basis of definite nutritive properties. Mushroom protein was found to be a "partially incomplete" protein or one similar to gliadin of wheat or hordein of barley. Properly supplemented, the mushroom is entirely suitable as a source of protein. Of course it is recognized that only relatively small amounts of protein in the human diet are ever furnished by mushrooms. The mineral content provides an additional source of iron and copper with the iron content of special significance because so many of the American dietaries are low in this essential element. *Agaricus campestris* was found to constitute an excellent plant source of nicotinic acid and riboflavin, a good source of pantothenic acid, and a fair source of vitamins, B₁, C, and K. Thus, although mushrooms will probably always be eaten for their innate flavor and taste appeal, they do possess definite food values and are not a purely luxury food in our war-time dietary.

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A Summary of Starter Solution Experiments on Tomatoes and Cabbage at State College, Pennsylvania¹

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THE results of four years' testing of starter solutions on tomatoes and one year's testing of starter solutions on cabbage are summarized in this report. In the experiments reported herein, solutions containing various fertilizer materials, alone or in mixtures, are compared with the usual water treatment when setting transplants into the field. In addition, the treatment of transplants with two growth promoting substances, indolebutyric acid and vitamin B₁, is reported.

In all these tomato experiments the Rutgers variety was used. In the cabbage experiment Marion Market was the variety. In all cases, flat grown plants were used. The seed was sown in flats in the greenhouse, and the seedlings were transplanted once to other flats before transplanting into the field. The spacing of the tomato plants in the field in 1938 was 3½ by 5 feet; in 1939 and 1940, 4 by 5 feet; and in 1941, 3½ by 4½ feet. The spacing of the cabbage plants in 1941 was 1½ by 2½ feet. The fertilizer application was 800 pounds per acre for tomatoes and 600 pounds per acre for cabbage applied broadcast with a grain drill just before field setting. The soil is Hagerstown silty clay loam and is relatively fertile. In 1938 and 1939 1 pint of starter solution or water was applied to each tomato plant, and in 1940 and 1941 ½ pint of solution or water was applied to each tomato or cabbage plant.

In selecting the treatment containing a mixture of Ammo-Phos and potassium nitrate and the treatment containing a mixture of di-ammonium phosphate and mono-potassium phosphate the author was guided by the results of starter solution experiments conducted by Sayre (1) at the New York Agricultural Experiment Station; and in selecting the indolebutyric acid treatment the author was guided by the results of experiments conducted by Stier and Du Buy (2) at the Maryland Agricultural Experiment Station.

The yields of marketable tomatoes for the various treatments are given in Table I. To show the effect of the starter solutions on earliness of yield, figures for early yield — the yield during approximately the first 3 weeks of the harvesting season — are given along with the yield for the whole season. In every case the results were treated statistically by the analysis of variance method, and the difference between two treatments necessary for significance (twice the standard error of difference between the means of two treatments) is given. If one examines the total yield records for tomatoes in Table I, it will be observed that statistically no treatment effected a significantly greater total yield than that of the water-alone treatment. It will also be found that statistically only one treatment was significantly lower in total yield than water-alone, and that was the indolebutyric acid treatment

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TABLE I—EFFECT OF STARTER SOLUTIONS ON YIELDS OF TOMATOES

Treatment Number	Ingredients Per 50 Gallons of Water	Yield of Marketable Fruit (Tons Per Acre)							
		1938		1939		1940		1941	
		Early Yield	Total Yield	Early Yield	Total Yield	Early Yield	Total Yield	Early Yield	Total Yield
1	3 lb. superphosphate (20 per cent)—1 pint per plant	3.27	12.82	0.65	14.80	—	—	—	—
2	6 lb. superphosphate (20 per cent)— $\frac{1}{2}$ pint per plant	—	—	—	—	1.05	6.20	6.28	14.39
3	1 pt. liquid phosphoric acid (75 per cent)—1 pt. per plant	2.86	14.17	0.80	14.15	—	—	—	—
4	2 pts. liquid phosphoric acid (75 per cent)— $\frac{1}{2}$ pt. per plant	—	—	—	—	0.83	6.50	—	—
5	3 lb. KNO ₃ and NaNO ₃ mixture (16 per cent N)— $\frac{1}{2}$ pt. per plant	—	—	—	—	—	—	4.76	14.32
6	4 lb. Ammo-Phos (11-48-0)—1 pt. per plant	2.70	13.24	0.56	13.00	—	—	—	—
7	4 lb. di-ammonium phosphate—1 pt. per plant	2.71	11.07	—	—	—	—	—	—
8	2 lb. superphosphate (20 per cent)+2/3 lb. KCl—1 pt. per plant	2.57	10.63	—	—	—	—	—	—
9	2 lb. superphosphate (20 per cent)+ $\frac{1}{2}$ lb. KNO ₃ —1 pt. per plant	2.40	14.41	—	—	—	—	—	—
10	1 $\frac{1}{4}$ lb. superphosphate (20 per cent)+2/5 lb. Cal-Nitro (16 per cent)+1/3 lb. KNO ₃ —1 pt. per plant	2.32	12.42	0.70	12.75	—	—	—	—
11	2 7/10 lb. Ammo-Phos (11-48-0)+1 3/10 lb. KNO ₃ — $\frac{1}{2}$ pt. per plant	—	—	—	—	1.33	7.03	6.60	14.82
12	1 $\frac{1}{4}$ lbs. (NH ₄) ₂ HPO ₄ +1 $\frac{1}{4}$ lbs. KH ₂ PO ₄ — $\frac{1}{2}$ pt. per plant	—	—	—	—	1.15	6.95	6.76	14.50
13	2 $\frac{1}{2}$ lbs. (NH ₄) ₂ HPO ₄ +2 $\frac{1}{2}$ lbs. KH ₂ PO ₄ — $\frac{1}{2}$ pt. per plant	—	—	—	—	—	—	6.32	12.38
14	8 lbs. 4-16-4— $\frac{1}{2}$ pt. per plant	—	—	—	—	—	—	6.77	14.16
15	12 lbs. 4-16-4— $\frac{1}{2}$ pt. per plant	—	—	—	—	—	—	6.44	14.16
16	Indolebutyric acid treatment*—1 pt. of water per plant in 1939, $\frac{1}{2}$ pt. in 1940	—	—	0.62	11.60	0.56	4.03	—	—
17	Vitamin B ₁ treatment†— $\frac{1}{2}$ pt. water per plant	—	—	—	—	0.79	5.05	—	—
18	Water alone—1 pt. per plant in 1938 and 1939, $\frac{1}{2}$ pt. per plant in 1940 and 1941	1.98	12.50	0.43	12.78	0.77	5.85	4.56	13.32
	Difference necessary for significance 19 to 1	0.73	3.46	0.30	2.22	0.24	1.38	0.79	2.04

*Roots of transplants placed in solution of indolebutyric acid (10 parts per million) for about 5 minutes immediately before field-setting.

†Roots of transplants placed in solution vitamin B₁ (10 parts per million) for about 5 minutes immediately before field-setting.

in the 1940 season. However, it must be noted that certain treatments actually did outyield the water-alone treatment for two or more years, and sometimes by sizeable margins, even though the margins were statistically not significant. The treatments to be noted with this fact in mind and the increases in total marketable yield in tons per acre produced by them over that produced by the water-alone treatment are as follows: The superphosphate treatment—0.32 tons in 1938, 2.02 tons in 1939, 0.35 tons in 1940, and 1.07 tons in 1941; the phosphoric acid treatment—1.67 tons in 1938, 1.37 tons in 1939, and 0.20 tons

in 1940; the Ammo-Phos and potassium nitrate mixture treatment — 1.18 tons in 1940, and 1.50 tons in 1941; and the di-ammonium phosphate and mono-potassium phosphate mixture treatment (at the lower concentration — $2\frac{1}{2}$ pounds to 50 gallons) — 1.10 tons in 1940 and 1.18 tons in 1941. If one examines the early yields of tomatoes in Table I it will be observed that there were several treatments that produced significantly greater early yields than the water-alone treatment. These treatments and the corresponding increases in early marketable yield in tons per acre which they produced over water-alone are as follows: superphosphate treatment — 1.29 tons in 1938, 0.22 tons in 1939, 0.28 tons in 1940, and 1.72 tons in 1941; liquid phosphoric acid treatment — 0.88 tons in 1938, 0.37 tons in 1939, and 0.06 tons in 1940; di-ammonium phosphate treatment — 0.73 tons in 1938; the Ammo-Phos and potassium nitrate mixture treatment — 0.56 tons in 1940, and 2.04 tons in 1941; the di-ammonium phosphate and mono-potassium phosphate mixture treatment, $2\frac{1}{2}$ pounds to 50 gallons — 0.38 tons in 1940 and 2.20 tons in 1941; the di-ammonium phosphate and mono-potassium phosphate mixture treatment, 5 pounds to 50 gallons — 1.76 tons in 1941; the 4-16-4 fertilizer treatment, 8 pounds to 50 gallons — 2.21 tons in 1941; and the 4-16-4 fertilizer treatment, 12 pounds to 50 gallons — 1.88 tons in 1941. One of the interesting features about these results was the fact that the superphosphate alone and liquid phosphoric acid alone treatments were in most cases practically equal to or better than any of the other treatments in early and total yield (including the treatments furnishing all three major plant nutrients — nitrogen, phosphorus, and potassium) in every year except the 1940 season. The early part of the 1940 season was abnormally cold and wet compared with the other years in which these tests were conducted. It is the author's opinion that nitrogen and possibly potassium were limiting factors in the treatments in 1940 probably because the activity of soil micro-organisms was at a low ebb and consequently the releasing of these particular elements in an available form was taking place at too slow a rate. In 1941 the potassium and sodium nitrate mixture did not produce a significantly greater early yield, nor total yield, than that of water alone. All this seems to indicate that phosphorus is usually the most necessary element in a starter solution for tomatoes, at least under the climatic and soil conditions at State College. However, it would be the author's recommendation to use a starter solution containing all three major plant nutrients for tomatoes because the added cost is insignificant, and because in cold and wet seasons nitrogen and potassium might be limiting factors. As to which complete starter solution to use it does not seem to make much difference. There is some advantage, perhaps, in using fertilizer materials that dissolve completely (such as the di-ammonium phosphate and mono-potassium phosphate mixture treatment) as compared with using fertilizers or fertilizer materials that do not dissolve completely, but leave a sludge in the bottom of the barrel or other container used for mixing (such as 4-16-4 commercial fertilizer or mixtures containing Ammo-Phos or superphosphate). As to the proper concentration to use for starter solutions, these tests indicate that $2\frac{1}{2}$ pounds of the di-ammonium

phosphate and mono-potassium phosphate mixture to 50 gallons is as good as or better than 5 pounds of the same mixture to 50 gallons of water; and that 8 pounds are as good as or better than 12 pounds of 4-16-4 fertilizer to 50 gallons of water. The use of the two growth promoting substances used in these tests, indolebutyric acid and vitamin B₁, did not prove beneficial for tomatoes, at least not in the concentrations and with the methods used in these tests.

The treatments and yield records for one-year's testing of starter solutions on early cabbage are presented in Table II. Total yield as well as yield in the first cutting are included to give some indication

TABLE II—EFFECT OF STARTER SOLUTIONS ON YIELDS OF EARLY CABBAGE (1941)

Treatment Number	Ingredients per 50 Gallons of Water	Yield of Marketable Heads (Tons Per Acre)	
		Yield in First Cutting	Total Yield
1	6 lb. superphosphate (20 per cent)— $\frac{1}{2}$ pt. per plant	8.67	14.90
2	1 $\frac{1}{2}$ lb. NaNO ₃ (16 per cent N)— $\frac{1}{2}$ pt. per plant	11.53	16.71
3	2 7/10 lb. Ammo-Phos (11-48-0) + 1 3/10 lb. KNO ₃ — $\frac{1}{2}$ pt. per plant	11.04	15.44
4	1 $\frac{1}{2}$ lbs. (NH ₄) ₂ HPO ₄ + 1 $\frac{1}{4}$ lbs. KH ₂ PO ₄ — $\frac{1}{2}$ pt. per plant	9.46	16.78
5	12 lbs. 4-16-4— $\frac{1}{2}$ pt. per plant	9.53	14.26
6	Water alone— $\frac{1}{2}$ pt. per plant	8.50	14.18
	Difference necessary for significance 19 to 1	4.32	3.19

of the effect of the starter solutions on earliness. It will be noted that no treatment produced a statistically significantly greater early yield nor total yield than the water-alone treatment. However, in spite of this fact, several conclusions will be attempted, especially since the experiment was located on an apparently uniform piece of ground. It will be noted that the water-alone treatment gave the lowest early yield (8.50 tons per acre) as well as total yield (14.18 tons per acre); and that the sodium nitrate treatment gave the highest early yield (3.03 tons per acre over the water-alone treatment) and within 0.07 tons per acre of the highest total yield (16.78 tons per acre), which was produced by the di-ammonium phosphate and mono-potassium phosphate mixture treatment. On the other hand the superphosphate-alone treatment produced only slightly greater yields (0.17 tons greater early yield and 0.81 tons greater total yield) than those produced by the water-alone treatment. These results indicate that nitrogen, and not phosphorus, must be a very necessary element in a starter solution for early cabbage (the cabbage in this experiment was set into the field on April 22nd), at least under the climatic and soil conditions at State College. The three starter solutions containing all three major plant nutrients—nitrogen, phosphorus, and potassium—produced greater early and total yields than the water-alone treatment did, and greater than that produced by the superphosphate-alone treatment with one exception. This exception was the 4-16-4 treatment, which did not produce a greater total yield than did the superphosphate-alone treatment. These same three starter solutions produced yields not greatly different from those produced by the sodium nitrate starter solution.

In spite of the fact that the sodium nitrate treatment seems to be as good as any other treatment, it would be the author's recommendation to use a starter solution containing all three major plant nutrients for early cabbage since the added cost is insignificant, and because the use of a complete starter solution would be insurance against lack of favorable response due possibly to local soil or climatic conditions which might cause one or more of the three major plant nutrients to be lacking in availability to the cabbage transplants.

CONCLUSIONS

Certain starter solutions are effective in materially increasing yields of both tomatoes and early cabbage, particularly early yields. The element likely to be most necessary in a starter solution for tomatoes is phosphorus, and the element likely to be most necessary in a starter solution for early cabbage is nitrogen. However, for the average grower it is recommended that a starter solution containing all three major plant nutrients (nitrogen, phosphorus, and potassium) be used on these crops so as to insure maximum response to starter solutions under all conditions of soil and climate. There undoubtedly are many combinations of fertilizer materials that are equally good for use in starter solutions. There possibly may be a prejudice by some growers against the use of crude fertilizer materials, since they do not completely dissolve in water. The starter solutions and their concentrations (when $\frac{1}{2}$ pint is applied to each plant) which were found to be most effective in these tests are the following: (a) $2\frac{7}{10}$ pounds of Ammo-Phos + $1\frac{3}{10}$ pounds of potassium nitrate to 50 gallons of water; (b) $1\frac{1}{4}$ pounds of di-ammonium phosphate + $1\frac{1}{4}$ pounds of mono-potassium phosphate to 50 gallons of water; (c) 8 pounds of 4-16-4 fertilizer to 50 gallons of water; (d) for cabbage, $1\frac{1}{2}$ pounds of sodium nitrate to 50 gallons of water; and (e) for tomatoes, 6 pounds of super-phosphate to 50 gallons of water.

Treatment of the roots of tomato transplants with 10 parts per million solutions of the growth promoting substances indolebutyric acid and vitamin B₁ did not result in increased yields. In fact, in one year, 1940, the total yields were significantly lower where the indolebutyric acid treatment was given.

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An Accurate Fertilizer Applicator for Field Test Plots

By J. P. FAIRBANK and P. A. MINGES, *University of California, Davis, Calif.*

A REQUISITE for research work with commercial fertilizers in field tests is a method whereby the materials can be uniformly placed in given locations at predetermined rates. The commercial applicators available lack the precision required for small test plots. Hand applications have not been satisfactory because of the inability to obtain uniform distribution and proper depth of placement. Four fertilizer applicators suitable for small test plot work have been constructed, all involving the same principle which is to discharge the fertilizer through the rear end of a horizontal oblong trough. The first three machines have already been described (1). The fourth, which is an improvement over the first three, is particularly adapted to use in applying fertilizer tests on vegetable and other row crops. This machine is pictured in Fig. 1.¹

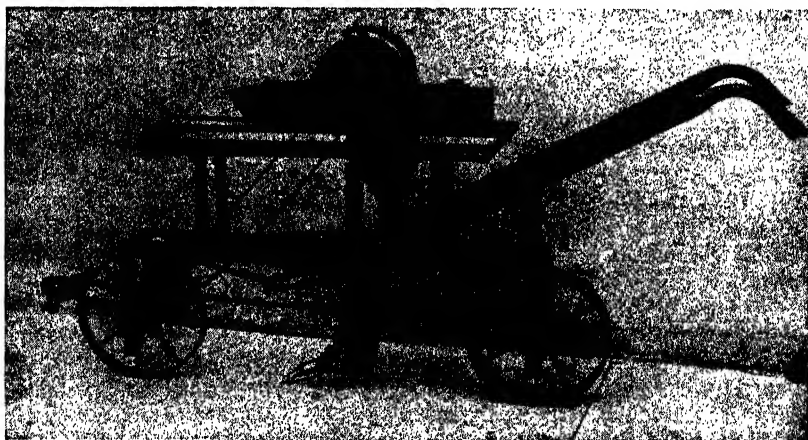


FIG. 1. The number 4 fertilizer applicator fully assembled. Note that the hopper is approximately midway in its course of travel. The shoe may be lowered and moved to the side so the fertilizer is near and below the plants.

The advantages of machine number 4 in test plot research are as follows:

1. The fertilizer is uniformly distributed in a continuous band throughout the row.
2. The machine is easily calibrated. The sole adjustment consists in regulating the length of travel of the hopper or carrier.

¹Credit is extended to F. G. Hall, mechanic in the Agricultural Engineering Division, who helped in the construction of the machine.

3. After the machine has been calibrated for a given length of row, various amounts of fertilizer may be applied to different plots with the same degree of uniformity without further adjustment.

4. There is no necessity to clean the hopper between changes in kinds of fertilizer materials, since the hopper is empty and clean at the end of each plot row.

5. The furrow opener can be moved laterally or vertically. Lateral adjustment amounts to 5 inches either side of center while the opener can be lowered to a depth of 8 inches below the soil surface.

6. The machine can be dismantled and carried in any sedan or coupe.

The hopper assembly (Fig. 2) is an important feature of this machine. The hopper (Fig. 2, B) consists of sheet metal sides and ends. The floor of the hopper is a continuous belt (Fig. 2, D) which is fastened at the front end of the hopper and as the hopper moves back, rolls under and forward. The 10-inch circular fiber brush (Fig. 2, A) sweeps a thin layer of fertilizer into the distribution tube. The carrier is propelled off the brush axle by means of a rack and pinion (Fig. 3, C) attached to the top of the trough. The brush and trough movement is powered by chains and sprockets from the front wheel.

The hopper on this applicator has an overall length of 28 inches, is 5 inches wide and $4\frac{1}{2}$ inches deep. The full length of travel of the trough is 17 inches, but this can be shortened to any desired distance by moving the lock (Fig. 2, H) along the rack. The belt, of 6-inch 3-ply rubberized canvas belting material is approximately 5 feet in length and is continuous around the two wooden rollers, (Fig. 2, E). The hopper assembly is $40\frac{1}{2}$ inches in length. Accurate distribution of

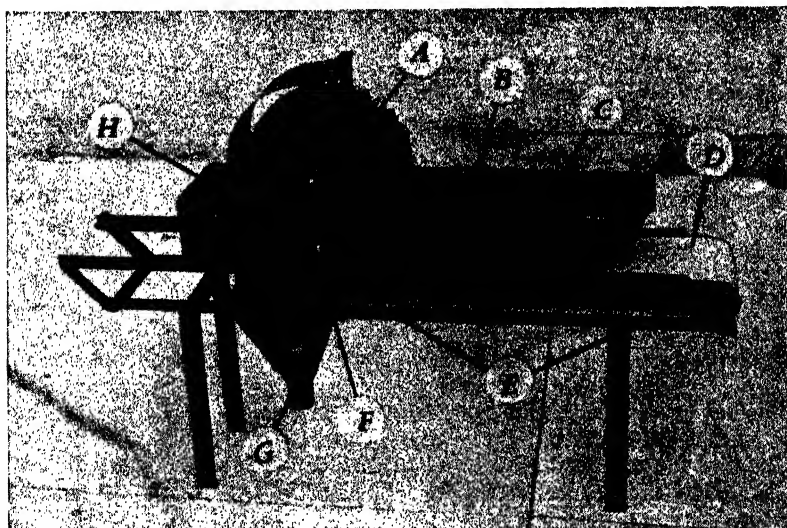


FIG. 2. The hopper and assembly of machine number 4. A, fiber brush; B, hopper or carrier; C, rack; D, continuous canvas belt; E, wooden rollers; F, gear engaging lever; G, distribution pipe; H, movable stop lock.

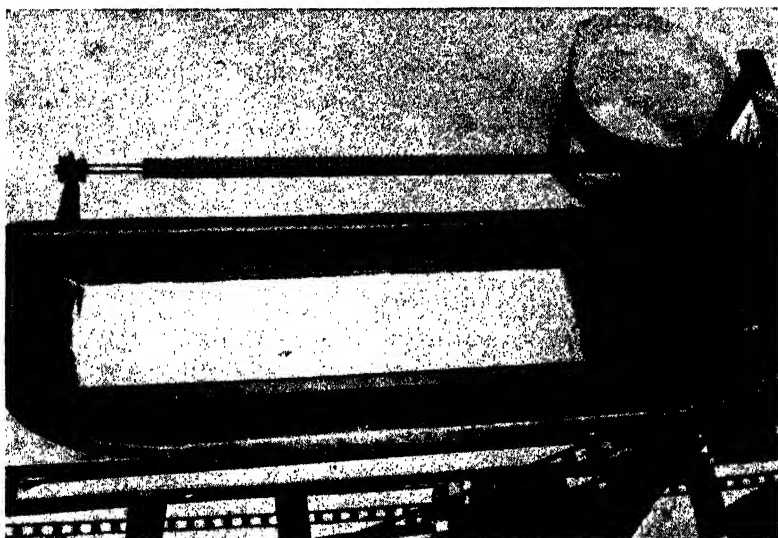


FIG. 3. Close up of the hopper of machine number 4. A weighed amount of fertilizer has been uniformly leveled over the bottom of the hopper. The brush prevents the fertilizer from spilling over the end of the trough while the material is being leveled and when moving distributes the fertilizer evenly.

fertilizer is obtained with amounts varying from $\frac{1}{4}$ pound to 10 pounds, which is the full capacity of the hopper.

Calibration of the machine consists in adjusting the travel of the hopper for the required length of row. An approximate adjustment is made by changing sprockets on the drive and driven wheels. Then by trial, the final adjustment is made by altering the starting position of the carrier. For example, to set this machine for 50-foot rows, it is necessary to use a 10-tooth drive sprocket and an 8-tooth driven sprocket and to set the hopper for the maximum travel of 17 inches. For 100-foot rows, we use a 6-tooth drive sprocket, a 10-tooth driven sprocket and the carrier is set for $14\frac{1}{2}$ inches of travel. This machine can be regulated for distances from a minimum of 15 feet to a maximum of 200 feet. Rates per acre are taken care of in determining the quantity of the fertilizer for each row of the plot.

The support for the shank of the furrow opener is the most important feature of the wheel frame. The middle of the frame is expanded 3 inches on each side to allow a 2-inch square metal bar 12 inches long to be inserted between the two frame bars. A U-bolt clamp secures the shank of the furrow opener to the square bar. By loosening the U-bolt, the furrow opener can be moved laterally and vertically or can be removed completely.

The shoe is a Md624 John Deere furrow opener with a beet cultivator shank. A half-inch steel turnbuckle is attached between the front of the frame and the bottom of the opener shank which should be

kept tight, to lend support when the shoe is in the ground. This turn-buckle is not needed for "light" or "loose" soils.

Miscellaneous parts include the cultivator handles, 15 feet of malleable No. 25 link chain, a 2-foot flexible metal seed tube and two 16-inch wheelbarrow wheels. The tire of the front wheel is $1\frac{1}{2}$ inches wide and that of the rear, $3\frac{1}{2}$ inches. The wheels are fastened to the axles by two set screws in the hubs. This arrangement allows the axle to be set tight for the chain drive and at the same time allows for easy removal. Five sprockets, 6-, 7-, 8-, 10- and 12-toothed, are necessary for regulating the travel of the carrier. The chain, which connects the front and rear wheels for the purpose of preventing undue wheel slippage, requires two identical sprockets.

When dismantling, the hopper assembly can be taken off by removing four bolts, one from each leg of the standard (Fig. 2). The handles, furrow opener and wheels can easily be removed from the wheel frame. No part of the machine exceeds 48 inches when dismantled, thus permitting it to be packed in an automobile.

The wheel frame and hopper assembly can be made from scrap pieces of steel. The cost of the parts that were purchased for this machine amounted to \$33.60 and approximately 60 hours of skilled labor were required for construction.

The amount of fertilizer required for each row of all the plots is measured out separately and sacked before entering the experimental plots with the machine. The proper adjustment as to the travel of the hopper and to the location of the furrow opener should be made by test on guard rows. The fertilizer for the first row is placed in the hopper and is evenly distributed over the bottom of the hopper, as shown in Fig. 3. A paint brush has been used to spread the fertilizer uniformly in the hopper. When the end of the row is reached, the drive gear is disengaged, the hopper is pulled forward to the predetermined starting point and the procedure repeated on the next plot in the same row.

If many experiments are to be conducted, a chart similar to that shown in Table I will aid in computing the amounts of fertilizer

TABLE I—POUNDS OF FERTILIZER PER 100 FEET OF ROW*

Row Spacing (Inches)	Rates (Pounds Per Acre)		
	100	200	400
12.....	0.23	0.46	0.92
18.....	0.34	0.69	1.37
24.....	0.46	0.92	1.84
30.....	0.57	1.15	2.28

*The above weights to the nearest one-hundredth pound, by slide rule, are computed from the formula $W = .000191SR$; where W = pounds of fertilizer per 100 feet of row; s = row spacing in inches; R = pounds per acre.

required per row. This chart can be expanded to include more spacings or rates. By interpolation, the weights for various row lengths can be computed.

The machine has been used with success on two row beds, on ridges and on flat plantings for both preplanting fertilization and side dress applications. If two bands of fertilizer per ridge or bed are desired, it

is necessary to make two trips with the machine. If very much of this work is to be done, it may be advisable to construct two similar machines. The machines could be used together for two band placement or separately when only one band is desired.

The soil type has not affected the efficiency of the machine for it has worked well in soils from sands to clays. However, care is necessary, regardless of the soil type, to prevent clogging of the furrow opener. If the shoe is gradually worked into the soil as the machine proceeds forward, little trouble will be encountered.

The machine is pulled either with a horse or small tractor. The hitchbar on the applicator has several holes in addition to a 4-inch off-set, which allows the operator to compensate for the side-draft concurrent with moving the furrow opener off center.

After the plots have been laid out and the fertilizer weighed, a 25 plot experiment with three 100-foot rows per plot can be completed in about 4 hours with the advantages discussed in the introduction.

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Field Plot Technique Studies With Tomatoes

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DATA from experiments designed for the study of differences between varieties and treatments may sometimes be used to compare the efficiencies of different arrangements of plots. However, uniformity trials, in which all plots receive the same treatment, are still needed to obtain a minimum bias in comparing efficiencies of widely differing arrangements and of plots of various sizes and shapes. It is the purpose of this paper to present the results of some such comparisons based on uniformity trial data with tomatoes. The relatively large area for a single tomato plant, the number of pickings required, and the perishability of the fruit generally force the experimenter to test fewer treatments or varieties at a time than he might test in a trial with grains or with many vegetable crops other than tomatoes. If plants are set by hand, the experiment must be kept to such size that there are no marked effects of difference in time of setting; if they are set with a transplanter, short rows become objectionable in cases where different lots of plants are put on different plots.

PROCEDURE

During the afternoon of June 5, 1941, a commercial lot of field-grown Indiana Baltimore plants, from southern Illinois, was set by hand in a field of Crosby silt loam at Lafayette. Plants were spaced 3 feet apart in 32 rows 6 feet apart and 330 feet long. However, each row was divided into three sections, of 34 plants each, by unplanted strips 12 feet wide, to provide roadways for picking up harvested fruit. Water was added to the soil around each plant to simulate the conditions produced by a transplanting machine. Fertilizer, 8-12-8, was applied later at the rate of about 500 pounds per acre, in bands $3\frac{1}{2}$ to 4 inches deep.

The experimental area was somewhat lower at the southwest corner and along the east edge, especially at the southeast corner, than elsewhere. All slopes were gentle, however, and no spots suffered from poor drainage. There were noticeable, but not pronounced, differences in surface soil color in different parts.

Prior to harvest time each row was divided into 4-plant plots, with 8 plots in each section of each row and with one plant left, as a guard, at each end of each section.

Pickings of all fruits ripe enough for canning were made August 21 to 22, August 29, September 9 to 11, September 17, September 25 to 26, October 8 to 11, and October 22 to 24.

TREATMENT OF DATA

Analyses of the data have been limited to the study of four hypothetical treatments or varieties, with which a high degree of accuracy is required, and of 16 treatments or varieties, with which less accuracy will suffice.

Plots of three different sizes were considered: Single row plots 288 feet long, not counting intervening unplanted strips; single row plots 96 feet long; and four-row plots 24 feet long. The very long plots contained 96 plants each, and the other two kinds 32 plants.

The 228-foot, single row plots were arranged in two different designs for the comparison of four hypothetical treatments. In making the arrangement, it was assumed that treatment 1 was a standard or check treatment and that comparisons of this treatment with any of the other three were more important than a comparison between, for example, treatments 2 and 3. For this purpose all even numbered rows (see Table I) were considered as belonging to treatment 1. Two methods

TABLE I—YIELDS OF ALL EIGHT-PLANT PLOTS IN UNIFORMITY TRIAL

North Edge												
Row	West Section				Middle Section				East Section			
1	42.9	59.2	80.7	74.6	69.0	77.3	61.1	72.2	51.3	59.2	58.0	88.3
2	50.5	72.5	83.1	82.5	76.4	89.4	74.1	75.7	57.8	62.0	70.6	100.9
3	40.4	58.8	70.9	91.1	59.4	73.3	52.1	68.5	62.3	60.5	78.4	68.2
4	42.6	56.7	58.2	98.2	54.1	70.7	50.6	70.1	46.9	45.9	63.5	89.6
5	47.6	53.9	74.5	97.1	75.0	74.6	54.4	86.8	57.1	60.1	55.4	89.5
6	54.8	68.4	80.6	90.0	86.9	60.5	59.6	90.4	51.5	57.7	58.2	77.8
7	58.9	77.8	95.6	111.7	89.5	89.2	76.3	93.4	60.6	60.6	65.1	93.2
8	54.0	77.8	83.6	111.4	86.2	67.5	62.5	83.3	72.8	69.4	55.7	72.8
9	57.1	72.4	82.6	105.0	93.5	76.5	72.2	99.0	71.5	68.2	60.3	76.1
10	63.9	70.6	89.7	105.6	81.8	71.8	67.4	86.4	66.2	74.2	51.9	69.5
11	50.4	67.5	83.0	88.4	49.4	49.8	41.6	65.2	62.7	58.3	53.7	63.9
12	51.0	52.1	95.1	86.2	56.2	53.2	40.3	62.2	60.3	57.8	56.5	53.7
13	50.4	62.3	97.4	109.0	55.8	52.8	41.1	60.4	65.0	74.0	54.9	68.0
14	70.0	81.6	89.4	103.6	59.9	58.2	45.1	56.8	57.8	63.8	62.4	73.9
15	72.5	84.7	97.2	100.0	58.0	51.0	51.0	51.3	47.8	80.3	73.3	69.5
16	78.5	68.9	86.4	93.2	48.9	53.3	40.2	53.5	49.8	66.4	70.7	63.9
17	71.8	83.7	107.0	98.2	57.9	45.7	38.0	55.2	56.3	74.4	65.9	60.8
18	68.4	73.3	78.7	60.1	45.1	40.9	34.3	64.6	51.5	61.1	75.6	59.0
19	82.6	71.5	70.4	55.7	44.4	34.7	44.6	56.7	55.8	55.6	83.5	68.2
20	80.5	78.7	72.2	54.3	50.9	42.1	52.3	62.9	58.6	68.2	94.8	71.3
21	100.4	83.0	67.4	55.4	44.4	44.0	46.3	69.5	62.2	67.6	83.1	75.8
22	109.6	89.7	71.7	63.3	47.2	47.0	60.9	67.0	56.9	68.8	74.4	79.6
23	94.7	80.8	65.6	53.8	44.7	47.7	36.4	65.6	51.8	63.3	88.0	79.1
24	103.0	93.8	64.7	62.1	53.9	42.4	49.1	83.9	57.6	76.4	91.9	78.9
25	101.5	94.1	73.3	67.6	63.8	45.5	43.6	72.0	53.6	81.6	100.4	70.7
26	101.9	71.0	70.0	71.4	60.2	46.2	47.8	85.1	70.2	74.8	95.7	99.6
27	83.9	72.6	70.6	68.9	37.1	50.5	58.2	96.8	69.1	83.4	96.9	89.7
28	70.9	60.6	56.5	55.2	25.0	35.3	56.7	85.0	80.0	70.6	71.9	87.5
29	71.3	57.4	52.9	44.9	41.2	52.4	49.7	74.1	57.7	71.5	83.1	95.1
30	53.9	54.2	43.1	46.5	38.1	53.3	52.3	51.4	67.0	71.4	82.7	97.5
31	57.6	48.7	43.4	48.7	44.1	48.9	49.0	66.6	63.3	102.9	85.0	92.0
32	48.3	54.4	43.9	50.5	59.0	78.8	42.1	85.2	71.2	79.2	88.1	99.9
South Edge												

of analysis were used on this arrangement of plots. For the first method row 1 was considered as a guard. The next three odd numbered rows were designated as belonging to treatments 2, 3, and 4, the next three made up the second group of treatments 2, 3, 4, and so on. Then the yields of all these alternate rows were expressed as differences above or below the average of the two adjoining checks. Finally, these differences were subjected to analysis of variance, without removal of variance due to block. Following the example of Goulden (2) in dealing with uniformity trial data, variance due to hypothetical treatments was here, as everywhere else in this paper, included with that for error in calculating the best estimate of variance due to error. But, in looking

up values of "t" in Snedecor's (4) Statistical Methods, degrees of freedom corresponding to actual error variance were used. Then from this variance were calculated the differences necessary for significance between treatment 1 and any other treatment and between treatment 2 and any other treatment. These two values differ only in that to arrive at the former it is unnecessary to multiply the standard error of the mean by the square root of 2, because this error is already really the standard error of the mean difference between treatment 1 and any other treatment.

Omitting the yield of row 20 as well as that of row 1, ordinary complete block analysis was made of the same yields while they were considered as belonging to the same treatments as they did in the analysis discussed above. In this case the plots were assumed to belong to five blocks of six plots each, the first block consisting of rows 2 to 7, the second of rows 8 to 13, and so forth. Thus, the plots were in five complete blocks with three plots of treatment 1 and one of each other treatment in each block.

A third use made of these long plots was in eight blocks of four adjacent single-row plots, one of each treatment. In this analysis, all comparisons were of equal importance.

Both 24 by 24 and 96 by 6 plots were likewise employed in the study of possible accuracy with four treatments, using data from all rows. The single row plots were analyzed as complete randomized blocks, each 96 by 24 feet, while the square four-row plots made up six Latin squares. These Latin squares occupied the north and south halves respectively of each of the three sections of the field. There were 24 replicates of each treatment for plots of both shapes.

In the study of the data as though they belonged to 16 treatments or varieties, only the two smaller types of plot were considered. The data for the south half of the west section were, in all cases, disregarded, because they were not needed for the five replications of the 4 by 4 lattice square arrangement.

With the data combined into 96-foot plots, the north end of the east section was laid out in four balanced incomplete blocks with four plots per block. The other half sections were similarly divided. These data were then analyzed by the appropriate procedure, as described by Weiss and Cox (5). The same data were then also treated as complete blocks of 16 plots each.

The plots 24 feet by 24 feet were combined in five lattice squares, each occupying a half section, and analyzed as such. The same plots were next considered as belonging to balanced incomplete blocks, first with the blocks made of plots lying north or south of each other and then with blocks of plots lying east or west of each other. Finally, as a matter of interest, the lattice squares were treated as simple complete blocks, although the shape and arrangement of plots seemed unadapted to the attainment of high accuracy by such analysis.

In addition to finding, for each arrangement, the differences necessary for significance between treatment means, the authors have calculated a measure of the accuracy of each design. This measure of accuracy has been used and explained by Cochran (1).

RESULTS

Vine growth was only moderately vigorous in this experiment, but plants became larger than is usual on Crosby silt loam. In some parts of the field vines met in the rows in spite of the wide spacing.

In Table I are given yields of each single-row plot of eight plants. These figures were derived, of course, from the yields of pairs of end-to-end four-plant plots. All calculations in this paper are based on these figures.

There were 49 missing hills out of a total of 3,072 possible record plants in the whole experiment. Although the exact location of these is known, their existence was disregarded in the data which appear in this paper.

Table II contains a summary of the accuracies of different plot arrangements and sizes. It is to be understood, of course, that the difference necessary for significance, in each case, applies only to differences between pairs of treatments which the experiment was designed to compare.

TABLE II—STATISTICAL COMPARISONS OF DIFFERENT EXPERIMENTAL DESIGNS

Number of Replicates	Arrangement of Replicates	Dimension of Individual Plots (Feet)	Dimension of Block, Row or Column (Feet)	Difference Necessary for Significance at 5 Per Cent Point (SMD) [†] (Tons Per Acre)		Accuracy 10 [‡] (SMD) [‡]
<i>For Four Treatments—Figures Based on Whole or Nearly Whole Area</i>						
5*	16 Alternate row checks	288 × 6	—	0.63 [†]	0.90 [†]	118 [†] 50 [†]
5*	15 Complete blocks	288 × 6	288 × 36	0.92 [†]	1.13 [†]	51 [†] 34 [†]
	8 Complete blocks	288 × 6	288 × 24		0.80	67
24	Complete blocks	96 × 6	96 × 24		0.56	128
24	Latin squares	24 × 24	96 × 24		0.56	130
<i>For Sixteen Treatments—Figures Based on Whole Area Except South Half of West Section</i>						
5	Balanced incomplete blocks	96 × 6	96 × 24		1.3	23
5	Complete blocks	96 × 6	96 × 96		1.6	16
5	Lattice squares	24 × 24	96 × 24		1.5	19
5	Balanced incomplete blocks	24 × 24	96 × 24		1.8	12
5	Balanced incomplete blocks	24 × 24	24 × 96		2.8	5
5	Complete blocks	24 × 24	96 × 96		2.5	6

*Five replicates of treatments 2, 3 and 4; 15 or 16 plots of treatment 1, the standard or check treatment with which other treatments are to be chiefly compared.

†The figure on the left in each column refers to comparisons between treatment 1 and any other treatment; that on the right refers to comparisons between treatment 2 and treatment 3 or treatment 4. Treatment 2 is any one of the treatments having five replicates.

‡To eliminate decimal points, the reciprocal of the variance due to mean differences was multiplied by 10.

The general mean yield was 10.24 tons for the whole field and 10.17 tons for the two and a half sections used in the studies involving 16 treatments. So the values given as tons per acre may be expressed as approximate percentages of the mean by multiplying them by 10.

In interpreting the figures in the last two columns at the right side of Table II, it must be borne in mind that the figures for four treatments are not quite comparable with those for the 16 treatment studies, because the former are based on a somewhat larger area.

The accuracy measures show, for example, that in an experiment, with four treatments the alternate row check method was 118/67 times

or 176 per cent as good as the 8-replicate, complete block arrangement when the comparisons of principal interest were those between treatment 1 and other treatments. Approximately 8(118/67) or 14 replicates, instead of 8, would have been necessary to obtain as low values for the standard error of the mean difference with the 228-foot plots in complete blocks as were gotten with the alternate row checks. Similarly, the figures show that with 16 treatments, balanced incomplete blocks, with individual plots 96 by 6, were 23/16 times or 144 per cent as accurate as corresponding complete blocks. To obtain equally small values for the standard error of the mean difference there would have had to be 5(23/16) or seven complete blocks instead of five. This increased accuracy resulted from the use of the proper arrangement and analysis in spite of the fact that if there had been no soil heterogeneity, the efficiency factor for the complex designs, as described by Weiss and Cox (5), would have made the incomplete blocks only 80 per cent as accurate as the complete blocks of 16 plots.

DISCUSSION

Although in Indiana the usual space left between rows is $3\frac{1}{2}$ feet, rows in this test were spaced 6 feet apart to avoid the effects of competition between rows and thus to permit the investigation of the possibilities of single row plots. Without going into the matter of the applicability of results from rows so widely spaced, it may be stated that further uniformity trials with rows more closely spaced have been contemplated from the beginning of this work. Evidence that on this soil type the 6-foot spacing eliminated inter-row competition is found in the fact that the rows on the north and south sides, which were originally intended to be guard rows, had the same vigor of growth and produced about the same average yield as did other rows.

Very often, especially in variety testing, there is one variety or a single treatment which is more or less standard. In such cases it is the principal purpose of the experiment to compare the yield of this treatment with each other treatment. In the case of tomatoes in Indiana, for example, the variety Indiana Baltimore is still standard. Other varieties must be demonstrated superior or inferior to this one. The results given in Table II indicate that when such a situation exists, the alternate row check arrangement, previously used by the senior author with potatoes (3) and with tomatoes, can provide rather accurate comparisons with few replications. Of course, very long plots must be used. It is a method adapted to machine transplanting and to experiments cooperative with growers. On the other hand, if all comparisons are of equal importance, the same total number of long, narrow plots in the experiment will apparently yield more accurate means when equal numbers of them are planted with each of the treatments or varieties than when the alternate row check method is used. At least this proved to be true for as few as four treatments.

For a relatively high degree of accuracy, where the comparison of two or more treatments with all other treatments is equally important, the use of a large number of replicates seems best. The 96 by 6-foot plots appear to be preferable to 24 by 24 plots, because they give about

equally accurate results and it is comparatively easy to keep fruit pickers from wandering from one plot to another if the plots are single rows.

For even as few treatments as 16, it was found desirable to arrange the plots in balanced incomplete blocks if the plots were long and narrow and in lattice squares if they were square.

SUMMARY

Calculations based on uniformity trial data with tomatoes showed that when one treatment or variety is to be compared rather accurately with a few others and when comparisons between any two of these other treatments or varieties are of secondary importance, the use of long alternate row check plots seems to be an efficient and practical design. From alternate check plots the data should be analyzed as differences between the yields of rows of treatments other than the check and the means of the two adjoining check rows. The use of smaller plots with 24 complete blocks did, however, give more reliable means for treatments than did the alternate row check method. With the complete blocks, of course, all comparisons were equally accurate.

Even with only 16 different varieties or treatments, the arrangement of five replicates of single row plots 96 feet long in balanced incomplete blocks produced a standard error of a mean difference as small as could have been obtained with seven replicates had the plots been grouped only in complete blocks.

For either 4 or 16 different treatments, single-row plots 96 feet long seem preferable to four-row plots 24 feet long when rows are spaced 6 feet apart. This statement is true when plots of each shape are arranged in designs best adapted to their shapes.

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Correlation Studies of Asparagus Comparing Yields of Various Shorter Periods with Ten-Year Yields

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IT HAS been established at this Station and by other investigators (1, 2, 3, 4, 5) that there is a wide variation in yields among asparagus plants of the same variety. The ability of a plant to produce a high yield of marketable spears over a long period of years is a primary consideration. This is especially true in California where it has been demonstrated on the peat sediment soils of the Sacramento-San Joaquin Delta that immediate replanting in old asparagus land is impractical. General observation in this area over a period of years leads one to the conclusion that the end of the commercial life of a planting is hastened by the early death of many plants and the rapid loss in size of spear in a high percentage of the remaining plants. Unpublished data at this Station show that the loss in spear size is more rapid in some plants than in others. The life of a bed could be materially increased by eliminating these undesirable types from a strain.

Correlation studies between early and total seasonal yields have been presented by Robb (4). Young (5) has found a correlation of $.913 \pm .065$ the number of summer stalks and yield over a 3-year period. Currence and Richardson (1) working with 4-year-old plants found a correlation of .710 and .760 respectively for female and male plants between yield and number of summer stalks, and a correlation of .660 and .650 respectively for female and male plants between diameter of crown and yield. They also show a correlation of .860 and .900 with female and male plants respectively between total yield (for the season) of 4-year-old plants and the total yield (for the season) of 5-year-old plants. This paper presents similar data based on 10 year yields.

In 1929 a breeding program was started at this Station to improve yields in asparagus. One hundred fifty-nine plants were selected from a 400-acre field of 2-year-old Mary Washington asparagus on the basis of number, size, color, cross section, and smoothness of summer stalks and the tightness of head as indicated by the height of branching. The selected plants were considered to be outstanding in three or more of these six characters but none were outstanding in all of them. These plants were removed with as much of the root system as was feasible and replanted at Davis in the fall of 1929. One hundred thirty-nine of these plants survived transplanting. They were harvested for the first time in 1932 and then only for a period of 4 weeks. In subsequent years they were harvested until the season ended which was usually between May 15 to June 1. All plants were given an equal opportunity to grow and were given the same treatment in cultural operations.

Individual plant performance records were taken on these 139 plants for 10 years. These data have been analyzed to determine if some criteria could be found that would be of aid in selecting parental stock for breeding purposes. These data are presented in Table I.

TABLE I—CORRELATION COEFFICIENTS BETWEEN YIELDS OF DIFFERENT PERIODS AND TOTAL YIELD FOR TEN YEARS

Total Yields for Ten Years	No. Plants	Total Yields		
		First Three Years	First Five Years	Six to Eight Years
All plants.....	139	0.77 ± 0.037*	0.85 ± 0.025	0.58 ± 0.057
Highest yielding 20 per cent	28	0.38 ± 0.016	0.43 ± 0.016	0.87 ± 0.180
Lowest yielding 20 per cent	28	0.64 ± 0.116	0.76 ± 0.085	0.83 ± 0.138

*Standard error.

The data in Table I were obtained by ranking the plants according to their total yields for the various yield and comparing these ranks with the ranks based on total yields at the end of 10 years. The data show a high correlation exists between yields at the ends of the 3- and 5-year periods with the yield at the end of 10 years when all plants were compared. The same is true for the low yielding group. However the correlations between the highest yielding 20 per cent for these periods are decidedly lower. It should be pointed out that in correlating a part with the whole it is realized that the correlation is influenced. But since all three groups of plants were treated alike this influence on the correlations should be the same. An examination of the individual plant records revealed that a number of plants in the high yielding group at the end of 10 years gave relatively low yields during the early years, and some of the high yielding plants the first few years were either dead or poor yielding at the end of 10 years.

Under California conditions the 8th, 9th, and 10th years are usually considered to be the period of highest yields. This would correspond to the 6th, 7th, and 8th years of these plants after transplanting in the breeding plot. The yields of this period were correlated with the total yields for 10 years and are presented in the last column in Table I. There is a high correlation between the yields for this period and the 10-year total yields for both the high and low yielding groups, although when all plants were compared a rather poor correlation was found. An examination of the individual plant yield records reveal that during this period many of the plants show declining yields while others show increasing yields. It seems to be a critical period in the life of the plants. Consequently it appears to be unsound to make selections based upon total yields alone. The slope of the yield curve on the higher yielding plants appears to offer a better index for selection during this period than earlier in the life of the plant.

Previously to resetting these plants in the breeding plot, detailed records were taken on the crowns to see if any of these crown char-

TABLE II—COMPARISON OF NUMBER OF BUDS AND BUD CLUSTERS AT TIME OF PLANTING BETWEEN HIGH AND LOW YIELDING PLANTS

	Mean Number Buds	Mean Number Bud Clusters	Mean Diameter Root (Mm)
Highest yielding 20 per cent	45.14 ± 13.463*	6.79 ± 2.103	5.64 ± 0.686
Lowest yielding 20 per cent	41.82 ± 12.434	6.36 ± 1.861	5.57 ± 0.280

*Standard error.

acteristics would be of aid in selection of high yielding crowns in the future. These data from the highest and lowest yielding groups are compared and are presented in Table II.

A study of Table II will reveal that there is no material difference between these two groups as to the number of buds, the number of growing points on the crown or between the mean diameter of the storage roots. One might suppose that the number of buds on a plant would be a reliable index of yield. Since this has not been found to be true in this experiment, the suggestion is offered that low yields on some plants may be due to a higher proportion of the buds remaining dormant than is the case with better yielding plants. Possibly also resetting these plants in the breeding plot after 2 years growth in the field may have disturbed the normal growth on some plants more than it did on others.

These data substantiate Young's (5) conclusion that the most careful selection of crowns at the time of planting will not eliminate all of the poor yielding plants. The only reliable method evolved so far to select high yielding plants is by taking individual plant records over a long period of time. As Currence and Richardson (1) have pointed out only a progeny test will reveal whether or not the high yielding ability will be inherited in the progenies.

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The Efficiency of Lattice Squares in Corn Selection Tests in New England and Pennsylvania¹

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SOIL heterogeneity contributes largely to the potential error in varietal trials and various plans have been proposed to offset it. The common element in all of these plans is replication, but the number of replicates and their disposition in the field varies from one design to another. One scheme, for example, replicates each variety equally often but arranges them in the same or in the reverse order each time. In systematic designs of this sort, varieties planted in adjacent plots are compared with a greater precision than those several plots apart and both are subject to an indeterminate bias. No adequate statistical method has yet been described for evaluating the results of varietal trials in systematic arrangements.

A major step in the improvement of varietal trials was the introduction of a random element in assigning varieties to plots in the field. Both randomized blocks and Latin squares eliminate bias from the comparison of yields. If many varieties are to be tested, however, the fertility of the plots in each randomized block might still vary considerably, while the necessity for as many complete replications as varieties would rule out the Latin square. The need for a closer control of field heterogeneity and greater flexibility in the field has been met by the introduction of the various balanced incomplete designs by Yates and his collaborators. In these designs the blocks, or their equivalent, contain a smaller number of plots than there are varieties, but pairs or groups of varieties occur together in the same block equally often. As first described, varietal yields and their errors were computed solely from a comparison of plots within blocks, ignoring differences between blocks. If field heterogeneity happened to be small, the new arrangement could be less efficient than complete randomized blocks. Recently, however, methods have been described for salvaging any pertinent information between blocks, so that this limitation has been removed and the newer designs contribute materially to the efficiency of the plant breeder.

After the introduction of a new statistical technique, some time may elapse before its value has been proved in practice and it is adopted generally. Since the new methods of calculation have become available, two papers have discussed the efficiency of the incomplete block designs known as the lattice and the lattice square in corn tests in Iowa. Zuber (7) superimposed hypothetical experiments upon the data from a field planted to a single variety but harvested and recorded in "plots" 2 rows wide by 5 hills long. He found a gain in precision with 5×5 and 7×7 lattice squares of 12 to 29 per cent over complete randomized blocks. Cochran (1) has examined the re-

¹The authors gratefully record their indebtedness to Professor W. G. Cochran, Iowa State College, for statistical advice and to Dr. L. W. Roberts, Connecticut Agricultural Experiment Station, for assistance in the computations.

sults of all corn varietal tests in Iowa from 1938-40, obtaining a mean increase in precision of 25 and 47 per cent for 5×5 and 7×7 lattice squares respectively, using 4-row by 5-hill plots. During 1940 and 1941, lattice squares with single row, 30 foot plots have been used extensively in corn varietal trials in New England and Pennsylvania by the Eastern States Farmers' Exchange. The present paper outlines procedure and reports our experience with this arrangement.

EXPERIMENTAL PROCEDURE

In experiments arranged in randomized blocks, each block contains one plot of each variety. Field heterogeneity between blocks can be segregated both from the comparisons of varieties and from the estimate of the experimental error. When the number of replicates equals the number of varieties, the same experiment may be arranged in a Latin square, each variety occurring once in each row and once in each column of plots. Field heterogeneity can then be isolated in two directions, that paralleling the rows and that at right angles to the rows and paralleling the columns. The improved control over field heterogeneity effected by Latin squares as compared with randomized blocks has been demonstrated in many studies. Lattice squares may be likened to randomized blocks with as many rows as columns of plots, in which the varieties are so arranged that the field heterogeneity associated with rows and columns can be removed with the same effectiveness as in Latin squares. Although each "square" must have the same number of rows as columns, it need not be square topographically, but the number of varieties is restricted to the square of the number of plots in one side, such as 3^2 , 4^2 , 5^2 , 7^2 , 8^2 , and 9^2 .

In the experiments reported here, lattice squares for testing 25 varieties with three replicates and for 49 varieties with four replicates have answered present needs. More varieties were tested in most localities both in 1940 and 1941, but in several independent sets. To avoid competition between early and late types, they were sorted into maturity classes which could be handled readily in groups of either 25 or 49. Varieties were assigned at random separately in each set of squares to the numbers 1 to 25 or 1 to 49. Each experiment in any one year, however, followed a standard plot arrangement, such as that shown below, without further randomization of rows and of columns as recommended by Yates (6). Although a more complete randomization is preferable, its absence here probably has not impaired the following comparisons to an appreciable extent.

The principle of the design will be evident from an inspection of either of the following patterns. Every variety occurs once and once only in the same row or column with every other variety. In the first replicate of the 5×5 squares, for example, variety 1 occurs in the same row as varieties 6, 11, 16 and 21 and in the same column as varieties 2, 3, 4, and 5; in the second replicate it occurs with varieties 9, 12, 20, 23, 18, 14, 22 and 10; and in the third replicate with varieties 7, 13, 19, 25, 24, 15, 8 and 17. This internal balance enables one to eliminate from varietal comparisons the field heterogeneity asso-

Replicate I					Replicate II					Replicate III				
1	6	11	16	21	18	21	4	7	15	24	5	6	12	18
2	7	12	17	22	14	17	25	3	6	1	7	13	19	25
3	8	13	18	23	22	5	8	11	19	15	16	22	3	9
4	9	14	19	24	10	13	16	24	2	8	14	20	21	2
5	10	15	20	25	1	9	12	20	23	17	23	4	10	11

Replicate I								Replicate II							
39	42	37	41	38	40	36		36	49	24	30	12	18	6	
32	35	30	34	31	33	29		26	32	14	20	44	1	38	
46	49	44	48	45	47	43		48	5	29	42	17	23	11	
11	14	9	13	10	12	8		21	27	2	8	39	45	33	
4	7	2	6	3	5	1		31	37	19	25	7	13	43	
18	21	16	20	17	19	15		9	15	46	3	34	40	28	
25	28	23	27	24	26	22		4	10	41	47	22	35	16	

Replicate III							Replicate IV						
3	22	37	18	48	14	33	5	16	45	25	34	14	36
49	19	34	8	38	4	23	22	40	20	49	2	31	11
13	32	47	28	2	17	36	46	8	37	17	26	6	35
26	45	11	41	15	30	7	38	7	29	9	18	47	27
39	9	24	5	35	43	20	21	32	12	41	43	23	3
29	6	21	44	25	40	10	30	48	28	1	10	39	19
16	42	1	31	12	27	46	13	24	4	33	42	15	44

The plots differed from those described by other workers in consisting of single 30-foot rows, planted by hand, so that one dimension was considerably shorter than the other. In grain experiments the

stand was thinned to single stalks 12 to 15 inches apart in rows spaced from 36 to 42 inches in accord with the practice in the area. In silage experiments the plants were spaced more closely, in 1941 at 8 inches. The application of fertilizers in bands followed the standard practice in the area. At the time of harvest a small quantity of corn was shelled from 20 to 25 ears in each grain plot for the determination of moisture by the Steinlite Moisture Tester and the yields adjusted to a weight of 70 pounds per bushel of ear corn at 15 per cent moisture. To obtain a correction for the green weight of silage, sample plants from each plot were dried down in a Wisconsin-type bin drier. The record showed the stand in each plot at harvest, so that yields could be adjusted to a constant stand by covariance if desired.

STATISTICAL ANALYSIS OF LATTICE SQUARES

The analysis of data from lattice squares has followed that described by Yates (6) with some changes in detail. For the convenience of the reader the calculation will be described as a series of instructions with a numerical example. The data in Table I were the yields

TABLE I--YIELD OF REGULAR HYBRID VARIETIES OF FIELD CORN AT FEEDING HILLS, MASSACHUSETTS (1940)

						Yr	R	r
I	1	2	3	4	5			
	109.3	108.5	83.1	101.4	88.2	490.5	-158.2	-14.3
	6	7	8	9	10			
	87.2	78.6	73.9	83.2	78.3	401.2	0.5	0.1
	11	12	13	14	15			
	74.9	82.6	68.3	80.1	79.5	385.4	112.2	10.1
	16	17	18	19	20			
	69.0	58.3	74.9	70.4	79.5	352.1	189.6	17.1
	21	22	23	24	25			
	73.9	81.6	71.7	72.4	80.8	380.4	114.9	10.4
Y _c	414.3	409.6	371.9	407.5	406.3	2009.6		
C	-12.7	106.7	99.4	30.5	35.1		259.0	
c	-0.7	5.8	5.4	1.6	1.9			
II	18	14	22	10	1			
	113.7	112.5	135.1	70.9	101.9	531.1	-208.0	-18.8
	21	17	5	13	9			
	77.4	88.7	86.9	76.5	92.0	421.5	-45.9	-4.1
	4	25	8	16	12			
	64.6	84.6	74.3	69.9	102.7	396.1	14.4	1.3
	7	3	11	24	20			
	83.4	72.1	95.2	72.7	95.5	418.9	-41.2	-3.7
	15	6	19	2	23			
	86.0	79.5	95.8	88.6	88.9	438.8	-59.7	-5.4
Y _c	435.1	437.4	487.3	378.6	471.0	2209.4		
C	-72.2	-55.7	-161.5	45.0	-96.0		-340.4	
c	-3.9	-3.0	-8.7	2.4	-5.2			
III	24	1	15	8	17			
	105.8	98.1	102.9	94.7	113.9	515.4	-213.8	-19.3
	5	7	16	14	23			
	74.6	56.6	61.6	62.9	60.6	316.3	196.6	17.7
	6	13	22	20	4			
	71.7	69.2	85.6	69.0	63.1	358.6	152.0	13.7
	12	19	3	21	10			
	93.2	87.3	94.8	78.7	81.9	445.0	-82.8	-7.5
	18	25	9	2	11			
	98.4	86.3	88.8	78.1	81.9	433.5	29.4	2.7
Y _c	443.7	397.5	433.7	383.4	410.5	2068.8		
C	-26.6	54.6	-15.9	97.4	-28.1		81.4	
c	-1.4	2.9	-0.9	5.3	-1.5			

G = 6287.8

in 5×5 lattice squares on each plot of regular hybrid varieties of field corn at Feeding Hills, Massachusetts, in 1940, in the same arrangement as used topographically in the field.

TABLE II—INITIAL AND ADJUSTED TOTAL YIELD FOR EACH VARIETY FROM THE DATA IN TABLE I, EACH THE SUM OF THREE REPLICATES

Variety	Y_v	W
1.....	309.3	253.9
2.....	275.2	271.7
3.....	250.0	226.0
4.....	229.1	226.0
5.....	249.7	240.8
6.....	238.4	241.7
7.....	218.6	237.5
8.....	242.9	227.0
9.....	264.0	258.2
10.....	240.2	216.8
11.....	252.0	250.2
12.....	278.5	281.6
13.....	214.0	244.4
14.....	255.5	268.4
15.....	268.4	250.9
16.....	200.5	237.4
17.....	260.9	255.9
18.....	287.0	288.1
19.....	253.5	253.5
20.....	244.0	273.1
21.....	230.0	229.5
22.....	302.8	303.8
23.....	221.2	242.6
24.....	250.9	240.9
25.....	251.7	267.9
Total.....	6287.8	6287.8

The first step in the calculation is to total the yields in each row ($= Y_r$) and column ($= Y_c$) of the three squares and enter the totals in the margins of the table together with that for each square or block ($= Y_b$) and for all plots ($= G$) (Table I). The totals for varieties ($= Y_v$) are listed in order from 1 to p^2 opposite their numbers (Table II), where p is the number of plots in one row or column. The capital letter Y will be used to designate a total yield of several plots and small y the yield of an individual plot. The subscripts r and c refer to rows and columns respectively.

COMPUTATION AS RANDOMIZED BLOCKS

Ignoring differences between rows and columns, an analysis of variance is computed as in any experiment in randomized blocks, separating the variation between squares or blocks, between varieties and their interaction or the error as indicated below.

	Degrees of freedom		Sum of squares	Mean square
	$p = 5$	$p = 7$		
Blocks	2	3	$S(Y_b^2)/p^2 - G^2/N$	
Varieties	24	48	$S(Y_v^2)/\frac{1}{2}(p+1) - G^2/N$	
Error	48	144	By difference	E
Total	74	195	$S(y^2) - G^2/N$	

where N = total number of plots.

Computed as above the ratio of the mean square for varieties to

that for error permits a legitimate test of significance for varietal differences, although one which is usually less sensitive than after the removal of row and column variation. Substituting the numerical values from Table I, the analysis of variance was computed as

	D. F.	Sum of squares	Mean square
Blocks	2	$(2009.6^2 + 2209.4^2 + 2068.8^2) / 25 - 527152.38 =$	842.58
Varieties	24	$(309.3^2 + 275.2^2 + \dots + 251.7^2) / 3 - 527152.38 =$	5476.69
Error	48	By difference	10078.41
Total	74	$(109.3^2 + 108.5^2 + \dots + 81.9^2) - 527152.38 =$	16397.68
Correction for mean		$6287.8^2 / 75 =$	527152.38

ISOLATION OF DIFFERENCES BETWEEN ROWS AND COLUMNS

The sum of squares for error is then subdivided into three parts, that associated with rows within blocks (or "squares,") that with columns within blocks and a residual error within rows and columns. Since no two varieties appear more than once in the same row or column, the varieties occurring together in the same row or column of one block will fall in every row or column of the other blocks. If their yields average higher when they occur together than when scattered among 10 other rows or columns, presumably the yields in that row or column have had an undue advantage in fertility and should be reduced proportionately. The difference between twice the yield of all the plots in any row or column and the sum of the yields on the same varieties in the other blocks or squares, therefore, is independent of varietal differences and a measure primarily of soil heterogeneity. Since differences between blocks have already been accounted for in the analysis of variance, the differences for rows and columns in each block are corrected for their mean in computing the sums of squares for differences between rows and for differences between columns.

Instead of isolating row and column differences directly from the individual plot yields, it is easier to compute the total excess or deficiency for each row ($= R$) and for each column ($= C$) from the total yields that have already been listed as

$$R = S(Y_r) \text{ for varieties in row } r, \quad -\frac{1}{2} (p + 1) Y_r$$

and

$$C = S(Y_c) \text{ for varieties in column } c, \quad -\frac{1}{2} (p + 1) Y_c$$

These are entered in Table I at the end of the respective rows and columns. In each block $S(R) = S(C) = G - \frac{1}{2} (p + 1) Y_b$, and that for each block will be distinguished by subscripts I, II, III, and so on. For the numerical example in Table I, the excess or deficiency for the first row and column in block I are

$$R = 309.3 + 275.2 + 250.0 + 229.1 + 249.7 - 3(490.5) = -158.2$$

and

$$C = 309.3 + 238.4 + 252.0 + 200.5 + 230.0 - 3(414.3) = -12.7$$

R and C for the remaining 14 rows and 14 columns are computed similarly.

The sum of squares for error in the preceding analysis of variance is then subdivided into the following three parts:

	Degrees of freedom		Sum of squares	Mean square
	$p = 5 \quad p = 7$			
Rows	12	24	$S(R^2)/\frac{1}{2}p(p^2-1) - \text{Corr. term}^1$	E_r
Columns	12	24	$S(C^2)/\frac{1}{2}p(p^2-1) - \text{Corr. term}^1$	E_c
Intra-row and column error	24	96	By difference	E_i
Total error	48	144	From preceding section	E

¹Correction term $(S^2(R)_I + S^2(R)_{II} + \dots + S^2(R)_N)/\frac{1}{2}p^2(p^2-1)$

Substituting the values from Table I, we find

	D. F.	Sum of squares	Mean square
Rows, from R	12	$(158.2^2 + 0.5^2 + \dots + 29.4^2)/30 - 1263.86 =$	7162.53
Columns, from C	12	$(12.7^2 + 106.7^2 + \dots + 28.1^2)/30 - 1263.86 =$	1517.65
Intra-row and column error	24	By difference	1398.21
Total error	48	From preceding section	10078.41
Correction term		$(259.0^2 + 340.4^2 + 81.4^2)/150 =$	1263.86

ADJUSTMENT OF VARIETAL YIELDS

The variation associated with rows and columns is usually larger and sometimes much larger than the residual variation. For an unbiased comparison of varieties, the effect of row and column differences upon the total yield of each variety must be reduced, so that they contribute no more than the residual variation. The difference between the expected yield in any given plot and the general mean is assumed to be the sum of three independent quantities, which will have the same value (a) for all plots within any one row, (b) for all plots within any one column and (c) for all plots planted with the same variety. The variation between the expected and the observed yields determines the experimental error. In practice the original or unadjusted total yield of each variety is taken as the starting point and corrected for the first and second of these quantities.

The varietal adjustment for each row ($= r$) and column ($= c$) is computed from the mean squares in the preceding paragraph as

$$r = \frac{2(E_r - E_i)}{p(p-1)E_r} R \quad \text{and} \quad c = \frac{2(E_c - E_i)}{p(p-1)E_c} C$$

If E_i is larger than E_r or E_c , assume that $E_r = E_i$ or $E_c = E_i$ as the case may be, giving r or $c = 0$ and the given adjustment is then unnecessary. Over all blocks $S(r) = S(c) = 0$ within limits of the precision of the computation, which may be used as a check. The adjustments for the example in Table I are

$$r = \frac{2(596.88 - 58.26)}{5 \times 4 \times 596.88} R = .0902R \quad \text{and} \quad c = \frac{2(126.47 - 58.26)}{5 \times 4 \times 126.47} C = .05393C$$

For the first row and column in block I, $r = .0902 \times -158.2 = -14.3$ and $c = .0539 \times -12.7 = -0.7$ and others were obtained similarly.

The adjusted total yield (W) for $\frac{1}{2}(p+1)$ plots of each variety can then be determined by adding to the original unadjusted total yield (Table II), the values for r and c for every row and column in which the variety occurs, thus $W = Y_v + S(r) + S(c)$. The sum of the adjusted yields should equal the grand total of $S(W) = G$ within the error of the calculation. The adjusted total is divided by the number of replicates to obtain the adjusted mean for each variety or $\bar{y}_v = W/\frac{1}{2}(p+1)$. For variety 1 in Table I, $W = 309.3 - 14.3 - 18.8 - 19.3 - 0.7 - 5.2 + 2.9 = 253.9$, and $\bar{y}_v = 253.9/3 = 84.6$.

To test whether the varieties have differed significantly in yield, the sum of squares for the adjusted yields may be computed as $S(W^2)/\frac{1}{2}(p+1) - G^2/N$, which is divided by the degrees of freedom to obtain the mean square for a test of significance. Here the sum of squares for the adjusted yields = $(253.9^2 + 271.7^2 + \dots + 267.9^2)/3 - 527152.38 = 3640.75$, with a mean of $3640.75/24 = 151.70$.

ERROR OF THE ADJUSTED YIELDS

Having obtained the most probable yield for each variety, we next require a mean square for error applying to these adjusted values. This will be larger than the error within rows and columns but usually smaller than that for the unadjusted values in randomized blocks. When it exceeds the mean square for error computed as in randomized blocks, the unadjusted values should be used throughout.

The adjusted mean square for error, as noted by Yates (6), is itself subject to a sampling error in the adjustment. In lattice squares with as few as 25 varieties, this may cause a small but appreciable loss of information. For the error in 5×5 lattice squares, a table by Yates can be used to correct the adjusted mean square for tests of significance. The proportion of information remaining in the comparison of rows ($= d_r$) and of columns ($= d_c$), after allowing for the error in estimating E_r and E_c , is interpolated from Fig. 1. The ratios

$$\frac{3 E_r - E_i}{2 E_i} \quad \text{and} \quad \frac{3 E_c - E_i}{2 E_i}$$

are computed from the mean squares between rows (E_r), between columns (E_c) and within rows and columns (E_i) and, entering these ratios on the abscissa, the corresponding ordinal values on the diagram are d_r and d_c respectively. For lattice squares with $p = 7$ or more, the loss of information is negligible and one may assume that $d_r = d_c = 1$.

In the present example, the proportion of information remaining from row comparisons, corresponding to the ratio $\frac{3(596.88) - 58.26}{2(58.26)} = 14.87$, may be interpolated from Fig. 1 as $d_r = .985$. For column comparisons the ratio $\frac{3(126.47) - 58.26}{2(58.26)} = 2.76$ gives $d_c = .957$ by the same figure.

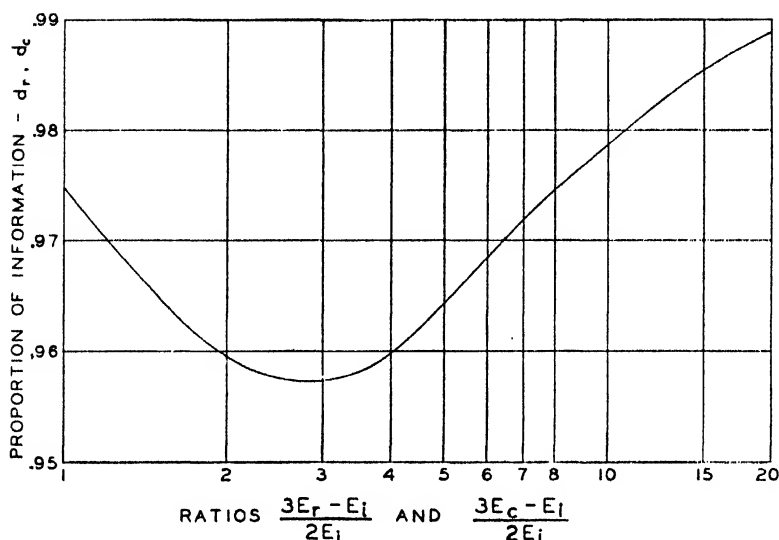


FIG. 1. Proportion of information retained in the weights for row (d_r) and for column (d_c) effects in computing the standard error of 5×5 lattice squares. Based upon the last table in reference (6).

The mean square for error for the adjusted yields (s^2) may then be computed as

$$s^2 = \left[1 + \frac{1}{p-1} \left(\frac{E_r - d_r E_i}{E_r} + \frac{E_c - d_c E_i}{E_c} \right) \right] E_i$$

which may be assumed to represent as many degrees of freedom as E_i . Where E_i is larger than E_r or E_c , the corresponding term is taken as 0 and drops out of the equation for s^2 . Its square root is the standard deviation (s) of a single plot. By dividing s^2 into the mean square between the adjusted varietal yields, one can test from the resulting variance ratio (F) whether they differed significantly from one another as a group by reference to standard tables (4). If so, the rank order of yield must represent at least in part a real differentiation between varieties.

For the numerical example in Table I, the mean square for error for the adjusted yields is

$$s^2 = \left[1 + \frac{1}{4} \left(\frac{596.88 - (.985) (58.26)}{596.88} + \frac{126.47 - (.957) (58.26)}{126.47} \right) \right] 58.26 =$$

$[1 + \frac{1}{4} (.9039 + .5591)] 58.26 = 79.57$ with 24 degrees of freedom. The variance ratio for the adjusted varietal yields may then be

$$\text{computed as } F = \frac{151.70}{79.57} = 1.91 \text{ with } n_1 = 24 \text{ and } n_2 = 24. \text{ The}$$

variance ratio expected at $P = .05$ is 1.98, from which it is evident

that differences in the yields of the 25 varieties in this experiment have not been demonstrated unequivocally.

Usually the plant breeder has most interest in the so-called "just significant difference". Presumably this is the difference in yield between any two varieties which would occur once in 20 times by chance alone if their expected yields were in reality identical. When two varieties differ by more than this limit, they are said to have unequal yields. Varieties that are selected from a long series on the basis of observed yields at the end of an experiment are separated into different classes more often than they should be by the usual "just significant difference". To offset this bias, the level of significance as read from the tables may be raised to a higher level or the t corresponding to fewer degrees of freedom may be used. Adopting the latter expedient, the just significant difference between any two adjusted total yields of $\frac{1}{2}(p+1)$ plots may be computed approximately as

$$\text{"just significant difference"} = t \sqrt{(p+1) s^2},$$

where t is read from Table III in reference (4) or its equivalent with $n = p-1$ at $P = .05$. In terms of mean yields, the corresponding

$$\text{"just significant difference"} = t \sqrt{\frac{4 s^2}{p+1}}.$$

Since the adjusted yields in Table II did not differ significantly, the "just significant difference" should be used with considerable reserve and more like a measure of scale on a map than for the critical discrimination of varieties. The computed "just significant difference" between any two adjusted total yields W in Table II is equal to $2.776 \sqrt{6 \times 79.57} = 60.7$. The yields for 21 of the 25 varieties fell within a range of 60 bushels. While the varieties with the largest and smallest yields may have differed significantly, the relative rankings of most of these hybrids probably would shift from one experiment to another.

ESTIMATION OF EFFICIENCY

Finally, the percentage efficiency of lattice squares in comparison with randomized blocks may be computed as

$$\text{percentage efficiency} = 100 \frac{E}{s^2}.$$

With the method of calculation described above this can never be less than 100 per cent and is frequently considerably more. In the

numerical example of Table I, the efficiency is $\frac{100 \times 209.97}{79.57} = 264$

per cent. By using lattice squares instead of randomized blocks, the varieties have been compared with three replicates with the same precision that would be expected from eight similar blocks without adjustment of the variation between rows and columns.

REPLACEMENT OF MISSING PLOTS

Not infrequently one or more plots are lost during the season, destroying the balance upon which the above calculation depends. Or an occasional very poor stand, with consequent reduction in yield, may increase the combined error disproportionately. These missing or markedly defective values are replaced from the other data in the experiment and the calculation is then completed with little change. Cornish (2) has described the estimation of missing values in lattice square designs from the information *within* rows and columns. How closely these values apply to the methods described in the preceding section is now under investigation. Meanwhile, his equation may be used provisionally in the more convenient form given below.

Let us suppose that a single plot is missing in a set of $\frac{1}{2}(p+1)$ lattice squares in which p is an odd number. Then a will stand for the missing value and R_a , C_a and T_a for the totals of the existing values in the row, column and square respectively in which a occurs. Let V_a be the total of the plots containing the same variety as a in the other squares and S_a the total of the rows and columns which contain this variety in the other squares. In the square with the missing plot there will be $2(p-1)$ varieties in the same row and column as a , and their total yield over all $\frac{1}{2}(p+1)$ squares may be designated as V_i . Finally over all squares, exclusive only of the single missing plot, the total yield will be called G' . Then the missing yield is given by the equation

$$a = \frac{\frac{1}{2}p(p-1)(R_a + C_a) - \frac{1}{2}(p+3)T_a + p(p-2)V_a - pS_a - pV_i + 3G'}{\frac{1}{2}(p-3)(p-1)^2}$$

Substituting the computed value in the place of the missing plot, the calculation is carried through in the same way as if the data were complete, except that the degrees of freedom for error within rows and columns are diminished by 1 for every computed value.

When several plots are missing, all but one are filled provisionally with the means from the other replicates for the same varieties. The remaining value is then computed as above, placed in position and the process repeated in turn for the provisional values. The computed estimates, however, form only first approximations and the entire operation should be repeated in rotation until stable values are obtained for each missing plot. With care in selecting the initial estimates and the order of solution, the calculation converges rapidly. When a whole row, column or variety is missing, the procedure is more complex and has been described by Cornish (3).

To illustrate the procedure, the plot for variety 1 may be assumed missing from square I (Table I). Then the missing value would be computed as

$$a = \frac{1}{16} [10(381.2 + 305.0) - (4 \times 1900.3) + (15 \times 200.0) - 5(534.1 + 471.0 + 515.4 + 397.5) - (5 \times 1924.9) + (3 \times 6178.5)] = 98.9$$

EFFICIENCY OBSERVED IN 1940 AND 1941

Two error terms have been determined for each of the 28 lattice square experiments in 1940 and 1941. The first mean square for

error (E) was not adjusted for differences between rows and columns, as if the tests had been arranged in ordinary randomized blocks. For the second, the overall effects between rows and columns were removed to obtain the adjusted s^2 described above. The ratio of the unadjusted to the adjusted mean square ($\times 100$) measured the percentage efficiencies listed in the last column of Table III. Converted to their square roots and divided by the mean yield for all varieties

TABLE III—PRECISION OBTAINED IN CORN VARIETAL TRIALS IN 1940 AND 1941 AND PERCENTAGE EFFICIENCY OF EACH TRIAL IN COMPARISON WITH RANDOMIZED BLOCKS (YIELDS OF GRAIN ARE IN BUSHELS PER ACRE AT 15 PER CENT MOISTURE AND OF ENSILAGE IN POUNDS PER ACRE DRY WEIGHT)

Year	Crop	Size of Square	Main Classes of Hybrid Corn	Mean Yield	Plot Standard Error		Efficiency (Per Cent)
					Unadjusted (Per Cent)	Adjusted (Per Cent)	
Slippery Rock, Pa.							
1940	Grain	5×5	Early	90.6	9.1	9.1	100
			Medium late F ₁ 's	80.2	13.9	12.6	121
			Late standards	92.5	9.6	8.0	144
			Late 3-way	88.6	9.5	7.0	185
1941	Grain	7×7	Late standards	79.9	11.4	10.8	111
Parkesburg, Pa.							
1940	Grain	5×5	Early standards	93.3	8.5	7.2	140
			Early 3-way	98.0	6.3	6.3	100
			Mid-season standards	101.7	7.6	6.8	122
			Late 3-way	101.3	7.6	7.6	100
Feeding Hills, Mass.							
1940	Grain	5×5	Very early flint dents	85.6	12.0	9.5	160
			Early flint dents	88.7	13.8	12.3	125
			Early	74.8	14.1	11.9	140
			Mid-season F ₁ 's	76.1	17.7	10.8	271
			Mid-season 3-way	89.4	15.0	9.2	262
			Experimental 3-way	80.9	17.3	12.0	207
			Late standards	83.8	17.3	10.6	264
			1941	Grain	7×7	Very early 3-way	91.4	13.2	12.1	119
Early	77.6	14.3				14.3	100
Mid-season standards	85.0	11.6				11.2	107
Late standards	86.0	13.5				11.9	129
Late experimental	95.4	14.5				11.4	163
North Haverhill, N. H.							
1940	Silage	5×5	Mid-season standards	5753	17.3	14.8	137
1941	Grain	7×7	Very early 3-way	60.7	11.7	10.2	133
Ellington, Conn.							
1940	Silage	5×5	Very early flint dents	7076	13.0	12.0	119
			Late standards	7861	10.7	9.6	124
			Late 3-way	6447	12.3	11.4	116
			Mid-season standards	7150	13.4	9.7	191
1941	Silage	7×7	Late	8194	13.7	13.1	109

in each test, they have been expressed as the percentage standard error of a single plot (Table III).

The field heterogeneity corrected by the design varied considerably from one locality to another and between the two years. The relative homogeneity of the fields used at Parkesburg in 1940 may be contrasted with the heterogeneity of those at Feeding Hills in the

same year, where the use of lattice squares doubled the efficiency and yet did not reduce the plot standard error to as small a value as that observed at Parkesburg. The tests at Feeding Hills in 1941, a dry season, were located on the same fields as those in 1940, a year with adequate rainfall, but a much smaller improvement could be attributed to the lattice square design. With soil moisture a limiting factor, local differences in soil fertility may have failed to express themselves, while irregularities in stand could have prevented a corresponding drop in the percentage standard error. Even though a given experimental field appears to be relatively uniform in one year, conditions in another year may expose an underlying heterogeneity where the local control provided by the lattice square design would be highly advantageous. Since no more field work is required than with randomized blocks, lattice squares represent an inexpensive form of insurance.

The mean precisions in the present experiments were comparable with those reported by Cochran (1) for 5×5 and for 7×7 lattice squares of 125 and 147 per cent respectively. The smaller 5×5 experiments in the present series gave a higher average precision (155 per cent) than the larger 7×7 tests (129 per cent), although this difference could be attributed equally to differences between years. It may be recalled that 30-foot single row plots were used in the eastern tests as compared with 4×5 hill-plots in Iowa, with little overall difference in efficiency. The percentage standard error per plot averaged substantially higher than those reported from Iowa, 9.9 as compared with 7.9 per cent for 5×5 squares and 11.6 as compared with 8.0 per cent for 7×7 squares. The procedure seemed to be equally effective for yields of both grain and ensilage, so that both have been included in the above means.

CORRECTION FOR UNEVEN STANDS

Each plot yield from which the above estimates were derived represented the total harvest for a constant area of one 30-foot row. Although originally the corn plants were spaced equally, usually at intervals of 1 foot, a number of plots had fewer than the standard number at harvest. In consequence, some plot yields were low due to a deficient stand rather than low soil fertility. Where irregularities in stand coincided with rows or columns, the calculation in lattice squares adjusted the combined effect of variations in both plot fertility and stand. A second, more efficient correction may be based directly upon a count of the number of plants in each plot at harvest.

Irregularities in stand can seldom be corrected satisfactorily by merely expressing the yield of each plot in "pounds per stalk" or the equivalent. When only an occasional plant is missing, those remaining may produce enough more to make up much of the loss, so the decrease in yield is not in direct ratio to the number absent. The discrepancy may be corrected instead from the observed relation within varieties between the yield of grain and the number of plants at harvest using covariance. The correction for covariance in lattice squares requires one other mean square for error and a mean product

for error in addition to the one described previously, that is: 1, the variance (s_y^2) computed from the total yield of each plot (y) as shown in the example; 2, a similar variance (s_u^2) computed in exactly the same way from the number of plants in each plot (u); and 3, a product variance (s_{uy}) paralleling 1 and 2 at every step except that the value for yield (y) is multiplied by that for stand (u) wherever these terms would be squared in computing 1 and 2. The ratio of the mean product for error (s_{uy}) to the mean square for error based upon stand (s_u^2) may be used as an average regression coefficient,

$b = \frac{s_{uy}}{s_u^2}$, for adjusting the yields to the basis of a uniform stand. The

variance of the yields adjusted for stand is equal to

$$\text{adjusted } s^2 = \frac{n_s s_y^2 - b n_s s_{uy}}{n_s - 1},$$

where n_s is the degrees of freedom in s_y^2 . The adjustment is probably unnecessary wherever the product ($b n_s s_{uy}$) does not exceed s_y^2 by more than two-fold.

The uniformity of stand may vary considerably from year to year. At Feeding Hills, for example, 78 per cent of the plots in 1940 had a perfect stand and only 3 in 525 plots had as many missing as 4 or 5 in 30 plants. On the same fields in the dry season of 1941, the number of plots with a perfect stand dropped to 35 per cent in 977, with many showing a wide departure from 30 (Fig. 2). The square at Feeding Hills with the most irregular stand in 1940 (very early flint dents) was computed by covariance, but s_y^2 exceeded the product $b n_s s_{uy}$, indicating that the remaining plants had made good the loss. The first two of the squares at Feeding Hills in 1941, which had the most uneven stands, were tested by covariance. For the series of very early 3-way crosses calculated as randomized blocks without adjustment for rows and columns, the correction for stand reduced the mean square for error from 146.2 to 82.4. After adjustment for rows and columns, a similar correction reduced s^2 from 123.3 to 73.4, an overall gain in efficiency of nearly 100 per cent from the combined effect of both adjustments. The variance for the series of early hybrids, which was not improved by the lattice square adjustment, fell from 123.0 to 93.1 after correction for stand. Under some growing conditions, therefore, irregularity in stand may contribute as much to the variability in plot yield as the heterogeneity between rows and columns in a lattice square.

The experimenter should be clear, however, as to the implications of the correction for unequal numbers of plants. The analysis of variance for stand, which is required for the adjustment by covariance, furnishes a test of the significance of differences between varieties. If the mean square for varieties does not exceed the experimental error significantly, as occurred in the 1940 square above, then differences in stand represent experimental errors that are no more characteristic of varieties than the differences between rows and columns in the lattice square. Covariance can be used without

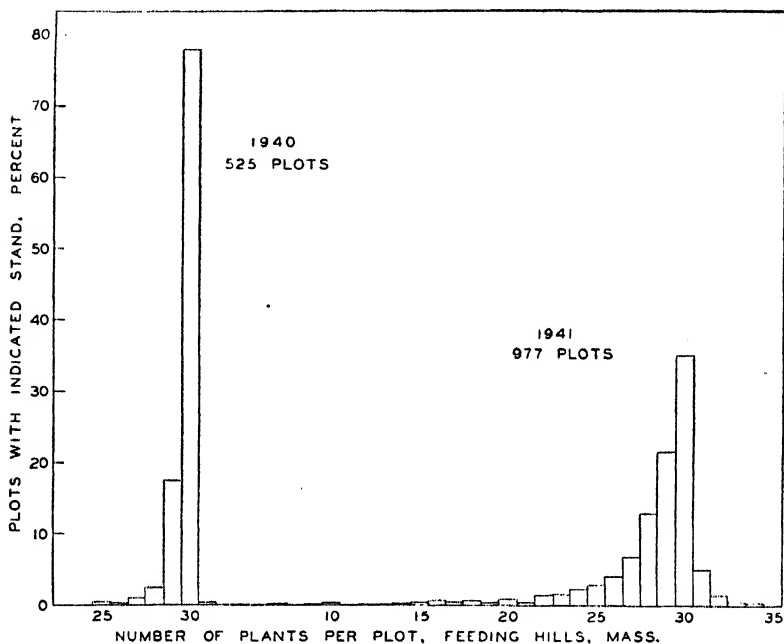


FIG. 2. Frequency distributions showing the difference in the uniformity of stand at Feeding Hills in 1940 and 1941.

any shift in the objective under test. However, if the varieties differ significantly, the computation without covariance compares the overall effect of mean yield per plant and the number of plants which survive in a plot, both of which influence the choice between varieties. The adjusted values, on the other hand, separates these two components, so that the yield for a uniform stand forms only part of the picture. Since plant breeders record many other characteristics during the growing season, such as germination, earliness, lodging and quality, which are used in conjunction with yield in reaching their conclusions, the adjusted yields after correction for stand would often serve their purposes better than the composite value, especially since only an occasional year may be sufficiently adverse to differentiate between varieties in this character.

The 1941 tests examined by covariance illustrate this condition very well, all of them showing a significant difference in stand between varieties. One complete series of 49 hybrids, predominantly very early 3-way crosses, was repeated at both Feeding Hills and North Haverhill, unfortunately without randomizing the numbering of the varieties separately in the two tests. After adjusting for row and column differences, the mean number of plants per plot at one location has been plotted against that at the other in Fig. 3. The stand was much more uniform at North Haverhill than at Feeding Hills, so much so that with the omission of a single case, the variance

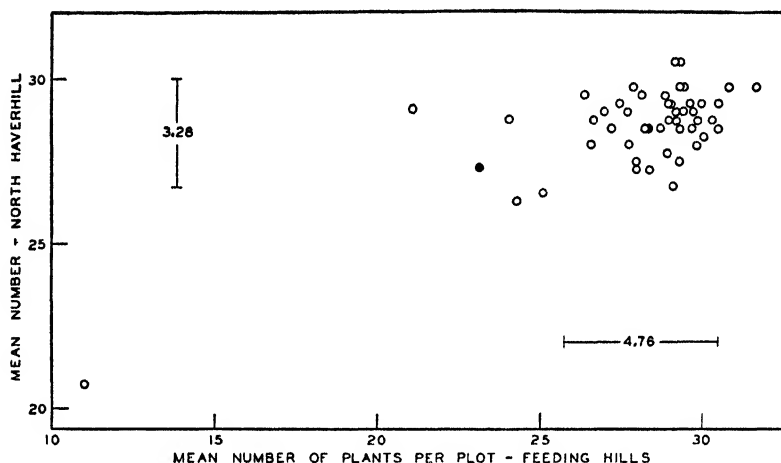


FIG. 3. Correlation in mean stand between varieties in identical 7×7 lattice squares at North Haverhill and at Feeding Hills, 1941. The scales represent the "just significant difference" in mean stand at each location. The shaded circles identify the two low-yielding varieties in Fig. 4.

between varieties, at North Haverhill barely exceeded that for error although at Feeding Hills the same 48 varieties still differed significantly. Yet even with the omission of this case, the varieties at the two locations were correlated significantly ($r = 0.35$, $P < .02$) in respect to stand. Presumably the unfavorable season at Feeding Hills afforded conditions not available at North Haverhill in 1941 for testing survival capacity, so that yields based upon a uniform stand would be more comparable than if one test included this additional factor and the other not.

Yields adjusted for rows and columns can be further corrected to a constant stand in units either of total or mean values, the former proving more convenient here. Adopting as the corrected value a stand of 28 plants per plot, since this was midway between the mean stands for the two tests, the difference of $4 \times 28 = 112$ minus the total observed for each variety was multiplied by the regression coefficient b and added algebraically to the total adjusted yield to obtain the corrected value. The coefficient b varied from test to test ($b = 2.59, 1.74$ and 1.16), but in every case was less than the "yield per stalk" obtained by dividing the total yield by the corresponding number of plants.

DISCUSSION

It has been shown how the lattice square design, aided by covariance in irregular stands, reduces field heterogeneity so as to discriminate smaller differences between varieties. Any given test, however, represents but one season on a single farm, and as such is a rather small sample for predicting the relative performance of the varieties in a group, especially when the differences between them are barely

significant. This is recognized by the plant breeder, who continues his experiments on the more promising strains on different farms over several years for his final selections. Each complete test is then one replicate in a wider and more variable universe than that represented within a set of lattice squares.

As an indication of the relative errors under the two conditions, the yields for several varieties have been compared in three groups that were tested in the same lattice squares in two or three different localities in 1940 and 1941. In two ensilage experiments at North Haverhill and at Ellington in 1940, 17 varieties were common to both. After adjustment for row and column effects, the consistency in their relative performance in the two regions was measured by the so-called interaction between variety and locality. In units of the plot standard error this proved to be 16.4 per cent of the mean yield for the two regions, although within lattice squares the plot standard error averaged only 12.0 per cent of the same mean. For comparing varieties to be recommended for both localities, the appropriate error is that based upon the variety by locality interaction. The error within squares would then be equivalent to the sampling or subplot error in the usual experiment.

A second group of 18 varieties was tested in grain experiments during 1940 in the three regions of Feeding Hills, Parkesburg and Slippery Rock. They were divided between three sets of 5×5 lattice squares at Feeding Hills and between two sets at Parkesburg and at Slippery Rock. In order to compare varieties only within series in any one locality, the adjusted total yields in each set were combined as if they formed three randomized blocks of seven varieties, of six varieties and of five varieties respectively, each based upon three subplots. In each group, the interaction of variety by locality exceeded the average adjusted error within lattice squares by a large margin, the ratio of the two variances being 2.6, 3.3 and 1.8 for the three groups respectively.

The third example consisted of 49 very early 3-way hybrids tested in identical 7×7 lattice squares in 1941 both at Feeding Hills ($42^{\circ} 10'$ north latitude) and at North Haverhill, New Hampshire ($44^{\circ} 10'$ north latitude). The correlation between localities in stand is shown in Fig. 3. The yields in the two tests have been plotted similarly against one another in Fig. 4 after correction for both row and column differences and for stand. Although two low-producing strains accounted for the larger part of the variation between varieties, the other 47 varieties still differed very significantly from one another. The interaction of locality by variety had about the same mean square as the larger of the plot errors for the two sets of lattice squares, the three variances being 80.31 for the interaction and 73.40 and 33.23 for Feeding Hills and for North Haverhill.

The greater variability in the wider sampling area balanced the increased precision from doubling the number of plots. Thus the ratios to their respective errors of the variances between the 47 better-yielding varieties were 2.06 for the total yields at both localities and 2.18 and 2.30 at Feeding Hills and at North Haverhill

individually. This was shown further by the discrepancies in the rank order of varieties in the two regions, as is evident from Fig. 4.

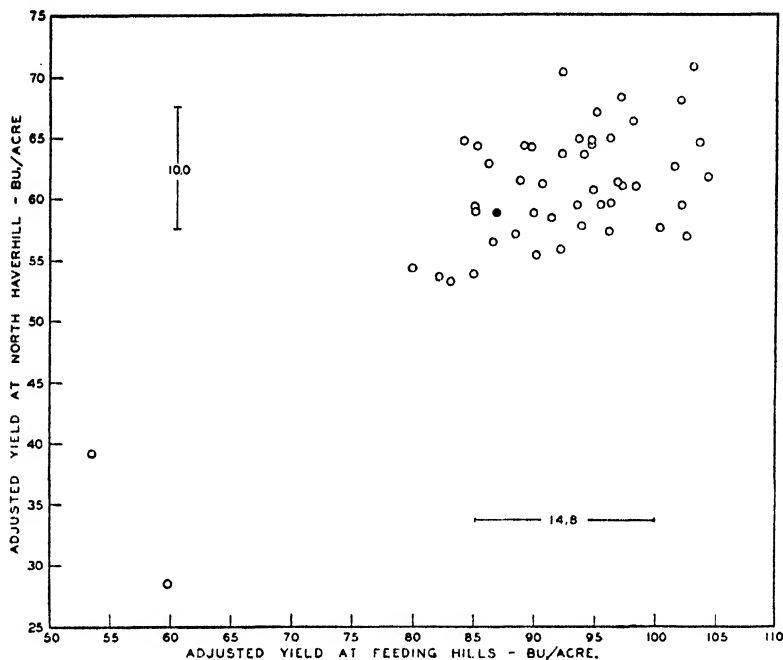


FIG. 4. Correlation in yield adjusted to constant stand between the varieties plotted in Fig. 3. The scales represent the "just significant difference" in adjusted yield at each location. The shaded circle identifies the variety with the poorest stand in Fig. 3.

The best-yielding variety at Feeding Hills, for example, ranked nineteenth at North Haverhill, while variety No. 2 at North Haverhill ranked No. 25 at Feeding Hills. It is also of interest that the variety with the significantly poorer stand proved a near-average yielder after correcting to constant stand (black circle in Fig. 4), while the two varieties with the poorest yield had quite acceptable stands (black circles in Fig. 3). Apparently the two criteria may vary independently. The discrepancy in the plot errors within series, indicated by the difference in the "scales" for the just significant difference in Fig. 4, raises the question as to the implications involved in summing or averaging yields from tests of unequal precision, and comparing tests from different climatic zones, a topic which will not be discussed here.

This brief examination of yields combined from different sets of squares emphasizes the desirability of retesting the more promising varieties in similar groups in different localities and years. Since the errors appropriate for these wider comparisons are interactions such as between varieties and years, between varieties and localities or

between varieties, years and localities, 5×5 lattice squares with three replications or 7×7 squares with four replications, repeated several times over the area of interest to the experimenter, should serve him better than more replicates and a higher precision within any one series.

SUMMARY

The 28 corn varietal tests reported here were laid out in 5×5 and 7×7 lattice squares in New England and Pennsylvania. The computation utilizing inter-row and inter-column information has been summarized in simplified form. The error of the adjusted yields has been adjusted for the reduced information in inter-row and inter-column estimates of the 5×5 lattice squares, and the validity of the "just significant difference" in varietal comparisons has been examined. The equation for computing missing values from intra-row and intra-column comparisons has been reduced to a simplified form. The present tests with 30-foot, single-row plots showed substantial gains in efficiency comparable with those reported for 4×5 -hill plots in Iowa. The yields for several squares in 1941 were corrected for uneven stand by covariance, which increased precision as much as the adjustment for row and column differences in these cases. Even though varieties differed significantly in uniformity of stand, yields adjusted to a constant number of plants per plot seemed more useful to the plant breeder than the uncorrected values. The interaction of varieties by locality in three series has been compared with the errors of the constituent lattice squares to illustrate the greater variability between varieties as the sampling area is expanded beyond the limits of a single farm.

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Effect of Temperature and Photoperiod on Seedstalk Development in Carrots¹

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CARROT and other so-called biennial crop plants often go to seed during the first year of their growth before they reach marketable size and this results in a financial loss to the grower. Experiments conducted by many investigators on other crops have shown that temperature, length of photoperiod, light intensity, and other ecological factors affect the initiation of flowering and the development of flowers and seeds. It seemed logical to expect that carrot plants might respond in a similar way to beets and other biennials. The studies reported in this paper were conducted to determine the effect of certain environmental factors on seedstalk development in the carrot. Major attention was given to a study of the influence of temperature and length of photoperiod on seedstalk development in plants that had reached the stage of edible maturity. Results of two experiments are reported here. In one experiment the plants were exposed to relatively low temperatures in the greenhouse, and in the other the roots were stored at 35, 40 and 50 degrees F in cold storage rooms prior to growing them at three ranges of temperature in the greenhouse.

EFFECT OF LOW TEMPERATURE IN GREENHOUSE ON SUBSEQUENT DEVELOPMENT OF SEEDSTALK AT THREE RANGES OF TEMPERATURE

Two experiments were conducted to determine the effect of temperature and length of day on seedstalk development in mature carrots, but results of only one such experiment are presented here. Plants for this experiment were grown in the gardens of the Department of Vegetable Crops, Cornell University from seed of the French Forcing variety sown June 27, 1940. The roots were harvested October 1 and 1,000 were potted in 4-inch pots in sterilized soil. These were divided into four lots and placed under four ranges of temperature as follows: 40 to 50 degrees F, 50 to 60 degrees F, 60 to 70 degrees F, and 70 to 80 degrees F. The plants placed in the 40 to 50 degrees F temperature were transferred later to the three other ranges of temperature, as shown in Table I, in order to determine the effects of relatively low temperatures on subsequent development of seedstalks at higher temperatures. The lots placed in the three highest ranges of temperature at the beginning served as check or control plants. Two lengths of day — normal day (9.1 to 11.8 hours) and continuous light — were used. To increase the length of photoperiod, electric light from 100-watt Mazda lamps was used at night. The lights were suspended 29 inches above the soil surface in the pots and 3 feet apart. At the termination of the experiment on February 22 all of the plants that had not formed seedstalks were examined for flower primordia. The number of plants

¹Paper No. 241, Department of Vegetable Crops, Cornell University, Ithaca, New York.

TABLE I—EFFECT OF EXPOSURE TO 40 TO 50 DEGREES AND 50 TO 60 DEGREES F FOR DIFFERENT LENGTHS OF TIME ON SUBSEQUENT DEVELOPMENT OF SEEDSTALKS OF CARROTS UNDER THREE RANGES OF TEMPERATURE AND TWO LENGTHS OF PHOTOPERIOD

Preliminary Treatment	Number Plants	Number Seed-stalks	Number Primordia	Per Cent Reproductive	Number Plants	Number Seed-stalks	Number Primordia	Per Cent Reproductive
<i>Normal Length of Day 60 to 70 Degrees F</i>					<i>Continuous Light 60 to 70 Degrees F</i>			
Check 60 to 70 degrees F	15	1	1	13.3	—	—	—	—
15 days 40 to 50 degrees F	15	15	0	109.0	—	—	—	—
30 days 40 to 50 degrees F	15	11	4	100.0	12	8	0	66.6
45 days 40 to 50 degrees F	15	12	3	100.0	22	16	0	72.7
60 days 40 to 50 degrees F	15	13	2	100.0	15	15	0	100.0
15 days 50 to 60 degrees F	15	7	1	53.3	—	—	—	—
30 days 50 to 60 degrees F	12	7	1	66.6	12	8	0	66.6
45 days 50 to 60 degrees F	12	6	1	58.3	12	10	0	83.3
60 days 50 to 60 degrees F	12	4	6	83.3	12	6	3	75.0
<i>Normal Length of day 70 to 80 Degrees F</i>					<i>Continuous Light 70 to 80 Degrees F</i>			
Check 70 to 80 degrees F	15	0	0	0.0	—	—	—	—
15 days 40 to 50 degrees F	15	6	0	40.0	—	—	—	—
30 days 40 to 50 degrees F	15	9	1	66.6	12	7	0	58.3
45 days 40 to 50 degrees F	15	8	1	60.0	22	14	0	63.8
60 days 40 to 50 degrees F	15	8	2	66.6	15	15	0	100.0
15 days 50 to 60 degrees F	15	2	0	13.3	—	—	—	—
30 days 50 to 60 degrees F	12	2	1	25.0	12	2	0	16.6
45 days 50 to 60 degrees F	12	6	1	58.3	12	3	3	50.0
60 days 50 to 60 degrees F	12	8	2	83.3	12	11	0	91.6
<i>Normal Length of Day 50 to 60 Degrees F</i>					<i>Continuous Light 50 to 60 Degrees F</i>			
Check 50 to 60 degrees F	15	6	5	76.6	—	—	—	—
15 days 40 to 50 degrees F	15	9	4	86.6	12	3	3	50.0
30 days 40 to 50 degrees F	15	12	2	93.3	12	6	1	58.3
45 days 40 to 50 degrees F	15	15	0	100.0	22	15	0	68.1
60 days 40 to 50 degrees F	15	10	5	100.0	15	13	1	93.3

in which flower primordia had formed but seedstalks had not started to develop is given under the heading, Primordia, in Table I, and these added to the number of seedstalks make up the final percentage.

The data in Table I show that all of the plants that had been subjected to 40 to 50 degrees F for 15, 30, 45 and 60 days developed seedstalks or flower primordia when grown subsequently in the 60 to 70 degrees F temperature under normal length of day. Exposure to 40 to 50 degrees F was more favorable to seeding than was exposure to 50 to 60 degrees F for the same periods of time.

When the plants were grown at 50 to 60 degrees F, 76.6 per cent of the check plants developed seedstalks, or flower primordia, while the check plants grown at 60 to 70 degrees F developed only 13.3 per cent. Previous exposure to 40 to 50 degrees F for 15 and 30 days had little effect on flower initiation of plants grown subsequently at 50 to 60 degrees F, although it is probable that all of the plants would have been reproductive at this temperature had the experiment been continued a month or two longer.

Check plants grown at 70 to 80 degrees F did not develop flower primordia, but plants that had been exposed to 40 to 50 degrees F, or 50 to 60 degrees F for 15 days or longer did become reproductive at 70 to 80 degrees F. Exposure to 40 to 50 degrees F for 15 and 30

days was more effective in floral initiation than was exposure to 50 to 60 degrees F for the same lengths of time when the plants were grown subsequently at 70 to 80 degrees F. However, when the exposure was 45 and 60 days, 50 to 60 degrees F was as effective as 40 to 50 degrees F.

The normal length of day was slightly more favorable to initiation of flowering than was continuous light. At 50 to 60 degrees F the plants grown under the normal length of day produced a significantly higher percentage of seedstalks than did the plants grown under continuous light (odds > 999:1). In another experiment, plants grown at 60 to 70 degrees F under a 12-hour day produced a larger percentage of seedstalks than did a similar lot grown under 15 hours of light. It seems apparent that length of day is not a very important factor in the initiation of flowering in the mature carrot.

EFFECT OF STORAGE TEMPERATURE ON SUBSEQUENT DEVELOPMENT OF SEEDSTALK

An experiment was conducted in 1940-41 to determine the effect

TABLE 2—EFFECT OF STORAGE TEMPERATURE ON SEEDSTALK DEVELOPMENT WHEN GROWN SUBSEQUENTLY UNDER THREE RANGES OF TEMPERATURE

Length of Storage and Temperature (Degrees F)	Number Plants	Seedstalk Developed on Dates Given								P	Per Cent
		December		January		February					
		14	28	11	25	8	22				
50 to 60 Degrees F											
Check (not stored) . . .	15	0	1	1	1	3	6	5		73.3	
15 days at 35 degrees	15	0	0	6	6	6	12	2		93.3	
30 days at 35 degrees	15	0	2	12	12	13	15	0		100.0	
45 days at 35 degrees	15	0	0	5	7	7	10	2		80.0	
60 days at 35 degrees	15	0	0	1	5	10	15	0		100.0	
15 days at 40 degrees	15	0	7	13	13	15	15	0		100.0	
30 days at 40 degrees	15	0	0	6	7	9	12	1		86.6	
45 days at 40 degrees	15	0	0	3	3	6	13	1		93.3	
60 days at 40 degrees	15	0	0	1	7	13	15	0		100.0	
15 days at 50 degrees	15	0	3	6	8	12	12	2		93.3	
30 days at 50 degrees	15	0	0	4	6	6	8	3		73.3	
45 days at 50 degrees	15	1	4	5	5	7	8	1		60.0	
60 days at 50 degrees	13	0	0	3	8	10	10	3		100.0	
60 to 70 Degrees F											
Check*(not stored) . . .	15	0	0	0	0	0	1	1		13.3	
15 days at 35 degrees	15	0	3	4	4	5	5	0		33.3	
30 days at 35 degrees	15	0	2	2	2	4	4	0		26.6	
45 days at 35 degrees	15	0	0	0	0	4	5	0		33.6	
60 days at 35 degrees	15	0	0	2	2	5	9	1		66.6	
15 days at 40 degrees	15	0	1	4	5	7	7	1		53.3	
30 days at 40 degrees	15	1	6	6	8	10	10	0		66.6	
60 days at 40 degrees	15	0	0	3	5	11	15	0		100.0	
15 days at 50 degrees	15	1	2	2	2	2	2	2		26.6	
30 days at 50 degrees	15	2	4	4	6	9	9	0		60.0	
45 days at 50 degrees	15	2	4	5	5	6	6	0		40.0	
70 to 80 Degrees F											
Check (not stored) . . .	15	0	0	0	0	0	0	0		0.0	
15 days at 35 degrees	15	0	0	0	3	3	3	0		20.0	
30 days at 35 degrees	15	0	2	3	4	4	4	0		26.6	
45 days at 35 degrees	15	0	3	4	6	6	7	0		46.6	
15 days at 40 degrees	15	1	2	3	6	6	6	0		40.0	
30 days at 40 degrees	15	0	4	4	5	6	7	0		46.6	
45 days at 40 degrees	15	0	0	3	4	7	9	0		60.0	
15 days at 50 degrees	15	0	2	3	5	5	5	0		33.3	
30 days at 50 degrees	15	0	0	3	6	6	6	0		40.0	
45 days at 50 degrees	15	0	1	2	3	3	8	0		53.3	

of storage temperature on subsequent development of seedstalk under three ranges of temperature. Plants for this experiment were grown in the field at Ithaca from seed of the French Forcing variety sown June 27, 1940. The plants were harvested September 30 and 1,000 were selected for this study. Some of the roots were potted immediately in 4-inch pots and placed in the greenhouse under three ranges of temperature shown in Table II. The remaining roots were divided into three lots and placed in storage rooms held at 35, 40 and 50 degrees F. At the end of 15, 30, 45, and 60 days, some roots were taken from the storage rooms, were potted in 4-inch pots, and placed in the greenhouse under three ranges of temperature, 50 to 60 degrees, 60 to 70 degrees, and 70 to 80 degrees F. All were grown in the greenhouse under the normal length of day. The results of this experiment are given in Table II. These data indicate that, in general, the lowest greenhouse temperature (50 to 60 degrees F) was the most favorable for seeding. It is probable that all of the plants grown at this temperature would have gone to seed if the experiment had been continued for a month or two longer. At the end of the experiment on February 22, all of the carrots from five storage treatments had become reproductive. These had been stored 30 and 60 days at 35 degrees, 15 and 60 days at 40 degrees and 60 days at 50 degrees F.

Only one lot of plants grown in medium temperature, 60 to 70 degrees F produced 100 per cent seedstalks. This lot had been stored at 40 degrees F for 60 days prior to placing them in the greenhouse. By February 22, one of the check plants had begun to form a seedstalk and a second one had a flower primordium in evidence. Storage at 40 degrees was better than storage at either 35 degrees or 50 degrees F, and 50 degrees was better than 35 degrees F.

None of the check plants grown under 70 to 80 degrees F temperature showed evidence of flower primordia, which indicates that this temperature is too high for initiation of flowering. All storage lots showed an increase in seedstalks over the checks in the 70 to 80 degrees F temperature.

The Effect of Manures, Nitrogen Compounds and Growth Promoting Substances on the Production of Branched Roots of Carrots¹

By G. J. RALEIGH, *Cornell University, Ithaca, N. Y.*

IN THE older literature concerning vegetable production, the statement is often found that manures may cause branched or pronged growth of carrot roots. It is common observation that nematodes may also cause marked branching and irregular growth of carrots and that the nematodes may be carried to the field in refuse which gets mixed with the manure. Many growers in New York State apply manure on fields used for carrot production and in many sections a considerable amount of irregular root growth of carrots that does not appear to be due to nematodes is common. Experiments were started in December, 1940, to determine whether manure or urine would cause irregular growth of carrots grown in sand.

In this work all of the manure and urine used, with the exception of the mixture of manure and urine used in the field experiment, was caught as it fell from the animals in order that there might be no nematode contamination due to its coming in contact with refuse on the floor of the barn. Each sample was a composite of manure or urine from at least two animals.

With the exception of one experiment in the field on Dunkirk fine sandy loam, the work was done in greenhouses at Ithaca at temperatures ranging from 65 and 75 degrees except during the summer months when it was not possible to keep temperatures within that range. From mid-June to mid-September, 1941, the greenhouse glass was covered with a thin coat of white lead. From October through the cloudy periods in April, 1942, additional light was supplied from one-half hour before sunset to 10:00 p.m. Eight 100-watt Mazda bulbs were centered over 10 pairs of pots placed side by side on 2 inches by 4 inches wooden supports laid flat on the gravelled floor of the greenhouse.

Experiments in sand were made in 12-inch clay pots painted on the inside with asphalt paint. Forty pounds of No. 1 Berkeley grade quartz sand obtained from the Pennsylvania Glass Sand Company were used in each pot. From six to nine carrots were grown in each container. One liter of Hoaglands nutrient solution made up of KH_2PO_4 , 0.001M; MgSO_4 , 0.002M; $\text{Ca}(\text{NO}_3)_2$, 0.005M and KNO_3 , 0.005M was applied to each pot weekly the day following thorough leaching. All solutions contained Mn 0.5 part per million, B 0.5 part per million, Cu 0.02 part per million, Zn 0.05 part per million and Mo 0.05 part per million. Manure, urine, growth promoting substances, urea and similar compounds when used were added to the solutions immediately before applying for comparison with the check treatment receiving solutions only. The same strain of the Emperor variety was used in all of the experiments.

¹Paper No. 250. Department of Vegetable Crops, Cornell University, Ithaca, New York.

EXPERIMENTS IN SAND

Solutions with Manure and Urine:—Carrots were seeded December 14, 1940, and the following treatments applied on January 4, 1941: cow manure at the rate of 10 tons to the acre, horse manure at the same rate; cow urine, 2 per cent and horse urine, 2 per cent. The carrots were harvested on March 22. Marked branching of the roots resulted from the use of both the cow and the horse urine. The per cent branched roots for each treatment is shown in Table I. Carrots

TABLE I—EFFECT OF MANURE AND URINE ON BRANCHED GROWTH OF CARROT ROOTS IN GREENHOUSE

Treatment	Per Cent Branched Roots					Ave. of Replications
	Replications					
	1	2	3	4	5	
Cow manure 10 tons per acre.....	.0	0	25	33.3	0	11.7
Horse manure 10 tons per acre.....	0	0	0	0	0	0
Cow urine 2 per cent.....	25	66.7	71.4	87.5	62.5	62.6
Horse urine 2 per cent.....	71.4	71.4	85.7	83.3	100	82.9
Check.....	11.1	0	0	0	0	2.2

showing marked branching as a result of the use of cow urine and of horse urine as compared with those from the check treatment are shown in Fig. 1.

Quantities of cow urine varying from 0.06 per cent to 1 per cent and of horse urine varying from 0.06 per cent to 0.5 per cent as well as cow manure and horse manure each at the rate of 10 tons to the acre were applied on April 30 to carrots seeded March 30. When harvested on June 10 there was little difference resulting from any treatment due probably to the relatively large size of the carrots at the time the treatments were made. The experiment was repeated on June 26 on carrots seeded June 17. When harvested on August 9,



FIG. 1. Carrots from experiment 1. Upper left, cow urine 2 per cent; upper right, horse urine 2 per cent; and lower, check.

one-half of the carrots in the treatment receiving 1 per cent cow urine had branched roots. Almost 24 per cent of those receiving 0.5 per cent cow urine were also branched. Other treatments had no effect as indicated by the data in Table II.

Because of the lack of response to application of urine when applied on older carrots, 1 per cent and 2 per cent cow urine were applied on August 28 to carrots seeded August 12. Similar applica-

TABLE II—EFFECT OF MANURE AND OF VARYING QUANTITIES OF URINE ON BRANCHED GROWTH OF CARROT ROOTS IN GREENHOUSE

Treatment	Per Cent Branched Roots					
	Replications					Ave. of Replications
	1	2	3	4	5	
Cow urine 0.06 per cent.	0	0	0	0	0	0
Cow urine 0.125 per cent.	0	0	0	0	0	0
Cow urine 0.25 per cent.	0	0	0	0	0	0
Cow urine 0.5 per cent.	12.5	0	85.7	14.3	12.5	25.0
Cow urine 1 per cent.	75	50	50	37.5	37.5	50
Horse urine 0.06 per cent.	0	0	0	0	28.5	5.7
Horse urine 0.125 per cent.	0	0	0	0	0	0
Horse urine 0.25 per cent.	12.5	0	0	12.5	0	5
Horse urine 0.5 per cent.	11.1	0	0	0	0	2.2
Cow manure 10 tons per acre.	0	0	0	0	0	0
Horse manure 10 tons per acre.	0	0	0	0	0	0
Check.	0	0	10	0	12.5	4.5

tions were made on September 4 and 2 per cent cow urine was applied on September 11. Cow manure and horse manure at the rate of 10 tons to the acre were applied on August 28 only. Applications of horse urine at the rate of 1 and 2 per cent were made on August 28. Inability to obtain fresh horse urine prevented its use at a later date. As indicated in Table III the amount of branching was greatest on those carrots treated with the heaviest quantities of urine at the early date. The application of 2 per cent cow urine 2 weeks after the initial application had no effect. As in the previous experiments cow manure or horse manure that contained no urine had relatively little effect on the shape of the carrots.

Solutions with Growth Promoting Substances:—Indoleacetic acid, indolebutyric acid and naphthaleneacetic acid were applied at the rate of 5 and of 15 parts per million on January 4, 11 and 18 to carrots seeded December 14, 1941. The heavier application and in the case of naphthaleneacetic acid both concentrations caused marked curling of the leaves. The carrots were harvested March 22. Although marked deformity of the plants occurred as indicated by Fig. 2, no typical

TABLE III—EFFECT OF TIME OF APPLICATIONS OF URINE ON BRANCHED GROWTH OF CARROT ROOTS IN GREENHOUSE

Treatment	Per Cent Branched Roots					
	Replications					Ave. of Replications
	1	2	3	4	5	
Cow urine 1 per cent, August 28.	33.3	14.3	28.6	0	28.6	21.0
Cow urine 2 per cent, August 28.	66.7	28.6	62.5	66.7	66.7	58.2
Cow urine 1 per cent, September 4.	12.5	0	0	0	12.5	5.0
Cow urine 2 per cent, September 4.	12.5	20	22.2	62.5	33.3	20.1
Cow urine 2 per cent, September 11.	0	0	0	0	0	0
Horse urine 1 per cent, August 28.	25	25	11.1	22.2	25	21.7
Horse urine 2 per cent, August 28.	66.7	100	50	80	50	69.3
Cow manure 10 tons per acre, August 28.	0	0	0	22.2	0	4.4
Horse manure 10 tons per acre, August 28.	12.5	0	0	12.5	0	5
Check.	0	0	14.3	0	0	2.0



FIG. 2. Carrots from experiment 1. Upper left, indoleacetic acid 5 parts per million; upper right, indoleacetic acid 15 parts per million; lower left, indolebutyric acid 5 parts per million; and lower right, indolebutyric acid 15 parts per million.

branching of the carrots was noted.

Because of the marked injury resulting from the heavier applications of growth promoting substances, the experiment was repeated using more dilute solutions. The following treatments were applied on November 14, 1941, to carrots seeded October 18: indoleacetic acid 1.25 parts per million, 2.5 parts per million and 5 parts per million; indolepropionic acid at the same rates; indolebutyric acid 1.25 parts per million, and 2.5 parts

per million; naphthaleneacetic acid at the same dilutions; ethyl alcohol at twice the quantity used with maximum applications of any growth promoting substance. The carrots were harvested December 22. Practically no abnormally formed roots were found in any treatment.

Solutions with Supplemental Nitrogen Compounds:—In the experiment using cow and horse manure at 2 week intervals, ammonium carbonate was substituted for horse manure on September 11 due to inability to obtain the latter. No effect was noted from the use of that material on the relatively large plants.

On January 17, 1942, uric acid at the rates of 0.01, 0.02 and 0.04 per cent, urea at dilutions of 0.02, 0.04 and 0.08 per cent and ammonium hydroxide to supply 0.0056 and 0.0112 per cent ammonia were applied on carrots seeded December 26, 1941. The ammonium

TABLE IV—EFFECT OF URIC ACID, UREA, AMMONIUM CARBONATE AND AMMONIUM HYDROXIDE ON BRANCHED GROWTH OF CARROT ROOTS IN GREENHOUSE (EXPERIMENT 1)

Treatment	Per Cent Branched Roots					Ave. of Replications
	Replications					
	1	2	3	4	5	
Uric acid .01 per cent.....	0	0	0	0	0	0
Uric acid .02 per cent.....	0	11.1	0	14.3	0	5
Uric acid .04 per cent.....	0	0	0	0	0	0
Urea .02 per cent.....	0	0	0	0	0	0
Urea .04 per cent.....	25	50	0	0	0	15.0
Urea .08 per cent.....	75	50	0	60	14.3	39.9
Ammonium carbonate .02 per cent...	10	0	0	0	0	2.0
Ammonium carbonate .04 per cent...	0	12.5	25	0	0	7.5
Ammonium carbonate .08 per cent...	14.3	66.7	50	80	75	57.2
Ammonia .0056 per cent.....	0	12.5	0	0	0	2.5
Ammonia .0112 per cent.....	50	33.3	30	40	100	50.7
Check.....	11.1	0	0	0	0	2.2

hydroxide caused a precipitation in the solution and that treatment as well as that with ammonium carbonate was not applied when experiments were repeated and solutions applied on February 7 to carrots seeded January 15. In both of these experiments the higher concentrations of urea caused marked branching of the carrots as indicated in Table IV and Table V. The higher concentrations of ammonium carbonate and of ammonium hydroxide also resulted in marked branching of the roots. The type of branching was similar to that caused by cow or by horse urine as shown in Fig. 1.

TABLE V—EFFECT OF URIC ACID AND UREA ON BRANCHED GROWTH OF CARROT ROOTS IN GREENHOUSE (EXPERIMENT 2)

Treatments	Per Cent Branched Roots					
	Replications					Ave. of Replications
	1	2	3	4	5	
Uric acid .005 per cent.....	14.3	0	0	0	0	2.9
Uric acid .01 per cent.....	0	0	0	0	14.3	2.9
Uric acid .02 per cent.....	0	33.3	25	12.5	0	14.2
Urea .01 per cent.....	0	0	0	12.5	0	2.5
Urea .02 per cent.....	0	0	0	12.5	0	2.5
Urea .04 per cent.....	37.5	75	50	57.1	80	59.9
Urea .08 per cent.....	83.3	75	80	85.7	87.5	82.3
Check.....	12.5	0	0	14.3	0	5.4

EXPERIMENTS IN SOIL

Carrots were seeded in Dunkirk fine sandy loam soil on June 20, 1941, the day following the application and discing in of the following: cow manure; cow manure and urine; horse manure and urine; each at the rate of 20 tons to the acre: cow urine 10 tons to the acre and chicken manure 5 tons and 10 tons to the acre. Each treatment received, in addition, 1200 pounds of a 5-10-5 fertilizer to the acre. The crop was harvested on August 27. All of the manure and urine treatments, with the exception of the cow manure containing no urine, produced considerably more branched roots than the check treatment, but the results were variable and the amount of branching in the check plots was considerable. It was thought that some of the differences within treatments might have been due to inability to apply irrigation water evenly over the field.

Carrots were seeded on October 24 in asphalt-painted steel drums 22 inches in diameter and 17 inches deep filled with a relatively infertile Dunkirk fine sandy loam treated with 15 tons to the acre of a mixture of 2 parts of cow manure and 1 part of cow urine caught separately and a similar treatment thoroughly watered with the equivalent of 1 inch of rain and applied over an hour's time so as to simulate rainfall. The plants were watered twice with complete nutrient solution (Hoagland's) and were harvested on January 17. As indicated in Table VI twice as many carrots in the manure-urine treatment not watered heavily had branched roots as in the similar treatments watered heavily. The number of branched roots in the check treatment was very small.

TABLE VI—EFFECT OF A MIXTURE OF COW MANURE AND COW URINE ON BRANCHED GROWTH OF CARROT ROOTS IN SOIL IN GREENHOUSE

Treatment	Per Cent Branched Roots					Ave. of Replications
	Replications					
	1	2	3	4	5	
Cow manure and urine 15 tons per acre.....	15.4	28.6	7.7	21.4	28.6	20.3
Cow manure and urine 15 tons per acre, heavily watered.....	7.7	0	15.4	15.4	7.1	9.1
Check.....	0	0	0	7.7	6.0	2.7

DISCUSSION AND SUMMARY

Cow urine or horse urine applied with complete nutrient solutions to young carrots growing in sand so as to supply 1 per cent or more of urine caused marked branching of the roots. Cow manure or horse manure which contained no urine had relatively little effect. A number of growth promoting substances used in varying dilutions did not produce typical branching. The higher concentrations caused abnormal growth of the roots. Urea, ammonium hydroxide and ammonium carbonate all caused branching of carrot roots which could not be distinguished from that caused by urine.

In experiments under field conditions, chicken manure, cow manure containing urine and horse manure containing urine caused more branching of the roots than found in plots without manure but the results were variable and not conclusive. In experiments with soil in the greenhouse, a mixture of cow manure and cow urine caused branching of carrots grown in soil. Watering the soil heavily after applying the manure and urine mixture reduced the amount of branching. Additional experiments to determine whether manure or very high proportions of urea in a fertilizer may cause increased branching of carrots under field conditions are now being carried on.

A Study of the Time of Development of the Fibrous Sheath in the Sidewall of Edible Snap Bean Pods with Respect to Quality¹

By F. C. STARK, JR. and C. H. MAHONEY, *University of Maryland, College Park, Md.*

ROWE and Bonney (7) have presented a tentative method for the determination of quality in snap beans, based upon the measurement of the total content of fibrous material in the side wall of the pods. They give no indication as to the type of tissue being extracted by their method, but it is reasonable to assume that the extracted material would include the strings, the "fiber of the side wall", and the vascular bundles. Previous investigators (2, 3, 4, 5, 6) have reported the nature of the strings of the pod and its relationship to edible quality of the fruit, and have recognized the presence of an extremely variable structure, the "fiber of the side wall", but this latter structure has not been studied histologically in any detail. This structure has been termed by various workers as the "fibrous sheath" and "parchment".

Canners and field men realize that since the tough strings have been removed from the commercial canning varieties of snap beans by breeding, the most important character influencing quality of the canned pack is the "fiber of the side wall". The purpose of this study is to present data on the time of formation of the "fibrous sheath" of the side wall in the pods, particularly in its relation to edible quality, and to present information on the histological nature of the "fibrous sheath" in the edible pods of two varieties of snap beans.

EXPERIMENTAL PROCEDURE

Plantings:—Two varieties of snap beans, Giant Stringless Green Pod and Bountiful were chosen because it was known that the former variety does not exhibit any noticeable toughening in the side wall of the pods, whereas Bountiful exhibits a very pronounced toughening of the side wall in the more mature edible pods. The crop was planted in a Sassafras sandy loam on May 23, 1940, with 650 pounds 4-12-8 fertilizer applied in two bands 1 inch below and 2½ inches to the side of the seed. The pods were harvested on July 11 and were graded into the standard sieve sizes recognized by the Bureau of Agricultural Economics. The sieve size classification of round podded beans is based upon the thickness of the pods at their smallest diameter. There is no sieve size classification for flat podded beans; however, in this study Bountiful pods were graded under the same classification. On August 15, 1940, a fall crop was planted in the same block and was given the same treatments. In addition to pods harvested and graded into sieve sizes in the fall crop, blossoms were tagged on the day of anthesis and samples at daily intervals from open blossoms to 25 day old pods were

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obtained. The crop for commercial grading into sieve sizes was harvested on October 14. Samples of 150 grams of beans of each sieve size from both the summer and fall crops were canned in brine for fiber extraction.

Microtechnique.—After the pods were graded into their respective sieve sizes, samples were placed in formalin-acetic acid-alcohol fixing and killing solution. After fixing, the samples were embedded in "Tissuemat" and stained with the aqueous Safranin A-Fast Green combination. The phloroglucin-hydrochloric acid microchemical test was used for lignin and for the xylan-araban hemicelluloses.

RESULTS

The mean width of pods at different ages from anthesis is shown in Table I. Giant Stringless Green Pod, 20 days from anthesis in the fall crop, is a No. 4 sieve pod, while the pod of Bountiful is No. 1 sieve. At 25 days from anthesis Giant Stringless Green Pod is a No.

TABLE I—GROWTH OF SNAP BEAN PODS IN DIAMETER AT DAILY INTERVALS FROM ANTHESIS

Days from Anthesis	Giant Stringless Green Pod		Bountiful	
	In 1/64 Inches	Sieve Size	In 1/64 Inches	Sieve Size
14.....	10.2 ± 2.36*	1	—	—
15.....	—	—	—	—
16.....	—	—	8.2 ± 1.67	1
17.....	12.0 ± 2.11	1	—	—
18.....	13.0 ± 2.86	1	—	—
19.....	15.3 ± 2.50	2	10.6 ± 2.29	1
20.....	21.3 ± 2.60	4	12.2 ± 1.41	1
21.....	—	—	12.7 ± 1.73	1
22.....	18.0 ± 1.03	2	14.9 ± 1.07	2
23.....	18.3 ± 2.95	2	12.9 ± 1.04	2
24.....	23.1 ± 1.06	4	20.3 ± 1.52	3
25.....	26.1 ± 1.28	5	21.8 ± 2.54	4

*Standard deviations.

5 sieve pod and Bountiful is No. 4 sieve. It should be kept in mind that sieve size is measured by the diameter of the pod on its smaller axis, and that Bountiful is a flat podded bean with its earliest increment of growth being in pod length, followed by expansion in pod diameter and further expansion in length. This explains the small sieve size exhibited by the variety at 20 days from anthesis.

Examination of Table I shows that as the number of days from anthesis increased, there was a corresponding increase in mean diameter of the pods until 22 to 23 days from anthesis, when there was an abrupt drop in pod size. The decrease in pod diameter may be explained by the tagging technique and the prevailing temperatures. Blossoms were tagged over a 10-day period, and at the end of this 10-day period samples were collected. It was intended that sampling dates should be 10 days apart, but due to the danger of frost, more frequent samplings were made. During the first 5 days of the tagging period the mean night temperatures ranged from 60 to 75 degrees F, after which there was an abrupt drop to 40 to 55 degrees F. Therefore, samples tagged before the sixth day had a much greater accumulation of hour degrees of temperature than samples tagged after the first 5 days. When the

increase in pod diameter is correlated with the increased number of hour-degrees of temperature above the 55 degrees F base line, high degrees of association are obtained (Giant Stringless Green Pod, + 0.9786; Bountiful + 0.8908).

A cross section of a No. 2 sieve pod of Giant Stringless Green Pod is shown in Fig. 1, A. Fig. 1, B shows the side wall of a No. 6 sieve Bountiful pod. The "fibrous sheath" can be seen directly adjacent to and outside of the inner region of large, compact parenchyma cells (Fig. 1, A). In Fig. 1, B, this inner region of compact parenchyma has been crushed and is found directly inside the "fibrous sheath". The "fibrous sheath" in young pods (Fig. 1, A) consists of small, compact, almost isodiametric cells with no cell wall thickening. In more mature pods (Fig. 1, B; Fig. 2, C) the cells comprising this tissue become much larger and develop extensive thickening of the walls, but still retain their isodiametric shape and their compactness. Just outside of the "fibrous sheath" are large parenchyma cells in which the vascular bundles are embedded. The area outside of the region containing the vascular bundles consists of loose parenchyma. The pod (Fig. 1, A, B), then, is divided into four tissues, the inner region of parenchyma being the endocarp. The adjacent region, the mesocarp, consists of two layers, and the outer layer which contains the vascular bundles might be termed the outer mesocarp. The inner layer of the meso-

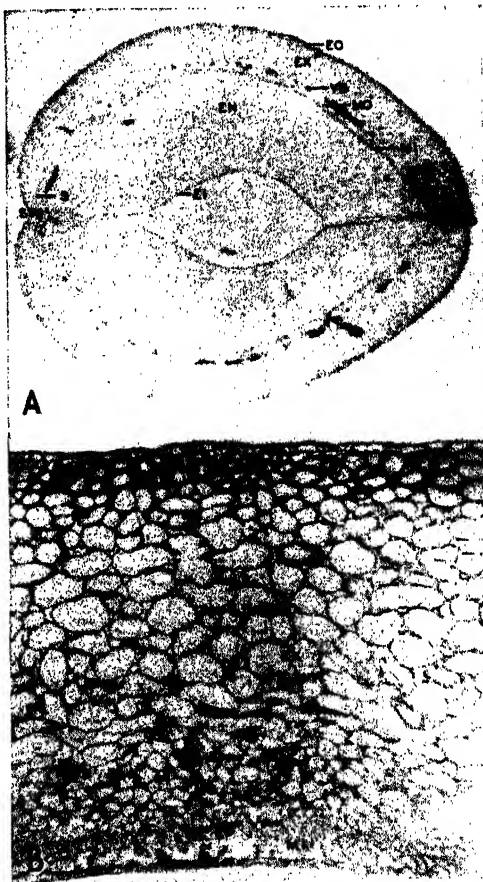


FIG. 1. Photomicrographs of cross sections of snap bean carpels. A, No. 2 sieve Giant Stringless Green Pod ($\times 16\frac{1}{2}$); B, No. 6 sieve Bountiful ($\times 98\frac{1}{2}$).

The following abbreviations were used: EO, outer epidermis; EI, inner epidermis; EN, endocarp; EX, exocarp; MI, inner mesocarp; MO, outer mesocarp; S, string; SD, dorsal suture; SV, ventral suture; VB, vascular bundle.

carp which has been called the "fibrillar layer", "parchment", or "fiber of the side wall", might histologically be termed the inner mesocarp. The outer region of parenchyma, then, might be termed the exocarp. Woodcock (8) has described these various tissues as they appear in young pods, but he has made no attempt to name them.

The cells of the inner mesocarp run at an oblique angle to the length of the pod, pointing in the direction of the styler end from the dorsal suture. The cells are curved, following the curvature of the carpel from suture to suture. In longitudinal section of mature Bountiful pods grown during the summer, these cells appear to be elongate, thick-walled cells retaining their protoplasts, and having end walls at right angles to the length of the cell.

Microscopic examinations were made on samples of pods fixed in FAA at daily intervals from the blossom stage to 25 days from anthesis during the fall crop. The inner mesocarp differentiates from parenchyma tissue. Bountiful exhibits at the date of anthesis a single-celled layer, separate and distinct from the tissue on either side, which is the initial of the inner mesocarp. Giant Stringless Green Pod, at the date of anthesis, shows no such prominent separation of tissues, and all cells are parenchymatous and of the same size. Three days from anthesis, the inner mesocarp in Bountiful can definitely be identified by the small cells of which it is composed. Giant Stringless Green Pod at 3 days from anthesis, however still shows no differentiation of tissues and the inner mesocarp cannot be identified. Six days after anthesis the region is completely oriented in Bountiful. Giant Stringless Green Pod, on the other hand, is just beginning the differentiation of the inner mesocarp at 6 days from anthesis and the region is not completely oriented until 9 days from anthesis. Complete orientation occurs 3 days later in the Giant Stringless Green Pod than in Bountiful. This difference of 3 days is important in a crop which takes only 18 to 25 days after anthesis for edible maturity of pods. In both varieties, the cells of the "fibrillar layer" show but little change in size or shape until 20 days after anthesis. At this time the cells begin to increase slightly in size, and at 25 days from anthesis average increase in cell size is quite marked.

Under conditions of the higher temperature and lower rainfall prevailing during growth of the summer crop, the inner mesocarp of No. 1, No. 2, and No. 3 sieve pods of Bountiful appear as small, close-fitting parenchyma, as described by Woodcock (8). The cell walls of the inner mesocarp begin to show a slight amount of thickening in the No. 5 sieve pods, and in the No. 6 sieve pods (Fig. 2, C) the increase in the amount of thickening of cell walls is very great. No. 6 sieve pods of the Giant Stringless Green Pod (Fig. 2, A) grown during the summer present a striking contrast to pods of the same size in Bountiful (Fig. 2, C). In development of the inner mesocarp only slight thickening of the cell walls has taken place in Giant Stringless Green Pod, while the cell walls in Bountiful are extremely thickened.

The mean temperatures for the time between first anthesis and harvest for the summer and fall crops were 70 and 56 degrees F. respectively, and likewise the rainfall was 0.88 and 1.47 inches.

Interesting comparisons may be seen in Fig. 2, showing the differences in the inner mesocarp of No. 6 sieve pods due to variety and due to season. Giant Stringless Green Pod, in the summer (Fig. 2, A) shows much less thickening of the cell walls than does Bountiful (Fig. 2, C) although the differences are not so marked in the fall (Fig. 2, B, D). As the cell wall thickening is less in the fall with cool temperatures and abundant rainfall than in the summer with higher temperatures and less rainfall, it appears that conditions of high temperatures and low rainfall have an accelerating effect on cell wall thickening.

Further comparison of the differences existing between varieties, between seasons, and between pod sizes, was made by measuring the width of the inner mesocarp of the

different samples with the aid of an ocular micrometer. The results shown in Table II represent the mean width, and standard error of the mean of 15 measurements from each pod. The increase in width of the layer in Giant Stringless Green Pod occurs in a constant proportion for both crops, except that the region in the No. 5 sieve pod decreases in width. The difference between No. 5 and No. 4 sieve pods is not sig-

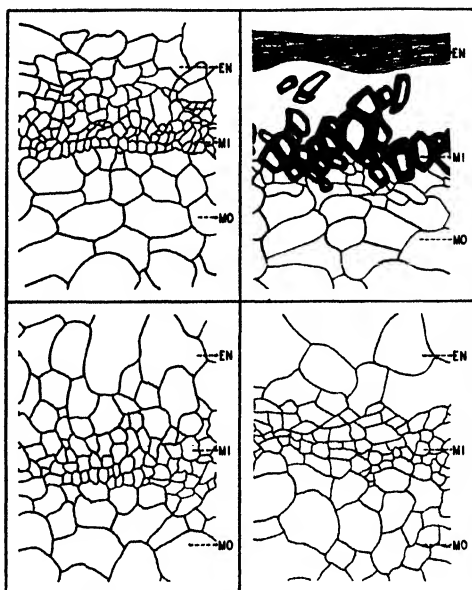


FIG. 2. Camera lucida drawings of cross sections of carpel side wall ($\times 508$). A, (upper left), No. 6 sieve Giant Stringless Green Pod, summer crop; B, (lower left), No. 6 sieve Giant Stringless Green Pod, fall crop; C, (upper right), No. 6 sieve Bountiful, summer crop; D, (lower right), No. 6 sieve Bountiful, fall crop.

The following abbreviations were used: EN, endocarp; MI, inner mesocarp; MO, outer mesocarp.

TABLE II—MEAN WIDTH OF THE INNER MESOCARP OF DIFFERENT SIEVE SIZES FOR TWO CROPS OF TWO VARIETIES OF SNAP BEANS

Sieve Size	Giant Stringless Green Pod		Bountiful	
	Summer (Microns)	Fall (Microns)	Summer (Microns)	Fall (Microns)
No. 1.....	1.31 \pm .0769	1.31 \pm .1573	1.18 \pm .0984	0.84 \pm .0568
No. 2.....	1.78 \pm .1063	1.61 \pm .0984	1.38 \pm .0656	1.38 \pm .1088
No. 3.....	2.15 \pm .1312	1.92 \pm .1981	1.78 \pm .1410	1.51 \pm .0927
No. 4.....	2.45 \pm .1485	2.89 \pm .1270	2.79 \pm .3239	2.15 \pm .1227
No. 5.....	2.28 \pm .1467	2.79 \pm .1751	4.97 \pm .3782	2.45 \pm .3137
No. 6.....	3.29 \pm .1884	2.96 \pm .2224	7.09 \pm .7662	3.12 \pm .1869

nificant; therefore, the decrease may be assumed to be due to sampling error. Both varieties show a more rapid increase in the width of the inner mesocarp in the summer than in the fall, and in both seasons the increase in width of the layer in No. 6 sieve over that in No. 5 sieve pods is proportionately very great. The differences pointed out in Fig. 2 are also evident in the mean width of the inner mesocarp of the No. 6 pods in Table II.

Microchemical studies on the preserved material showed that in no case was lignin present in the inner mesocarp. A positive test was given for the xylan-araban hemicelluloses, however, beginning with No. 2 sieve pods of Bountiful and No. 4 sieve pods of Giant Stringless Green Pod from the summer crop.

An effort was made to compare the histological observations with the per cent of fibrous material extracted by the Rowe and Bonney method (7). The samples used were No. 6 sieve pods of Bountiful (summer crop) and Giant Stringless Green Pod (summer and fall crop), and No. 5 sieve pods of Bountiful (fall crop). From the fall crop a sample large enough for extraction was not obtained of No. 6 sieve Bountiful. Prior to extraction, the strings and seeds were removed from the pods in an attempt to remove as much of the fibrous material, other than that of the inner mesocarp, as possible. The results given in Table III

TABLE III—PER CENT FIBROUS MATERIAL IN SNAP BEAN PODS WITH STRINGS AND SEEDS REMOVED, DETERMINED BY ROWE AND BONNEY METHOD

Sample	Fibrous Material (Per Cent)
No. 6 Sieve Giant Stringless Green Pod (summer).....	0.0575
No. 6 Sieve Giant Stringless Green Pod (fall).....	0.0127
No. 6 Sieve Bountiful (summer).....	0.6176
No. 5 Sieve Bountiful (fall).....	0.0349

show that the No. 6 sieve Bountiful grown in the summer is considerably higher in per cent of fibrous material than the No. 6 sieve Giant Stringless Green Pod grown in the summer. This relationship of the two varieties exists in the fall crop as well, although the difference is not so marked. Also, the pods of both varieties contain a higher percentage of fibrous material in the summer than in the fall. With respect to the per cent of inner mesocarp tissue, the percentages of fibrous material in all samples is somewhat high, due to the presence of the vascular bundles of the sidewall, which could not be removed.

SUMMARY AND CONCLUSIONS

Breeding work with the snap bean has resulted in the removal of exceptionally tough strings from the pods. Of the pod characters influencing edible quality, the most important character is the "fiber of the side wall".

The Giant Stringless Green Pod and Bountiful varieties of snap beans were grown in the field in the summer and in the fall. Samples of each of the six commercial sieve sizes were obtained from each

crop. In addition, pods were obtained from open blossoms to pods 25 days old, at daily intervals, during the fall crop.

Histological observations indicate that the tissue which has previously been called the "fiber of the side wall" and "parchment" is actually the inner mesocarp. The tissue begins as a one-celled layer of parenchyma and later develops into a region several cells in thickness. Orientation of the cells into a definite layer occurs 3 days earlier in the Bountiful than in the Giant Stringless Green Pod.

Increase in width of the inner mesocarp occurs in a constant proportion for both the Giant Stringless Green Pod and Bountiful until the pods reach the No. 5 sieve size. The increase in width of the layer in No. 6 sieve pods over that in No. 5 sieve pods is greater in Bountiful than in Giant Stringless Green Pod, and in both varieties the increase is greater in the summer than in the fall.

External factors appear to be responsible for the amount of thickening in the cell walls of the inner mesocarp of these varieties, with cool temperatures and high rainfall having a depressing effect on increased cell wall thickness. The thickening of the cell walls of the inner mesocarp in pods grown during 1940 is entirely hemicellulose, no lignin being found. Currence (2) reported that this tissue becomes lignified in the climatic conditions under which his plants were grown.

Fibrous material extraction of pods by the Rowe and Bonney method (7), with strings and seeds removed, verified the histological studies.

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Assimilation in Bean Plants of Nitrogen from Saline Solutions¹

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IT WAS pointed out in a previous paper (3) that increasing concentrations of either NaCl or CaCl₂ in the substrate influenced the percentage composition of nitrogen as well as of other nutritional elements in bean plants. Since plant performance is dependent upon the synthesis of inorganic nitrogen into the proteinaceous materials of active protoplasm, it became desirable to know to what extent modifications in plant response were associated with modifications in certain phases of nitrogen assimilation. Since nitrogen metabolism is conditioned by the status of carbohydrates in the plant, it was considered essential to carry out the investigation with plants grown at a season of the year when sunlight is at a minimum as well as when it is at the maximum. This report deals with plants grown under the former conditions.

The experimental technique by which these red kidney bean plants were grown has been previously described (3). Upon harvesting, the plant tissue was prepared for analyses by desiccation in a rapid current of air 70 degrees C. Nitrogen partition was carried out according to the technique described by Clark (1). Sugars were analyzed as per Tompsett's (5) procedure. Sucrose was inverted with invertase and starch was hydrolized with fresh salivary diastase.

The growth performance of these plants is presented in Table I.

TABLE I—AVERAGE GREEN WEIGHTS, TOP/ROOT RATIOS, AND DRY MATTER AS PERCENTAGE OF GREEN WEIGHT OF BEAN PLANTS AS INFLUENCED BY INCREMENTS OF NaCl AND CaCl₂ IN THE SUBSTRATE

	Base Nutrient (Gms)	NaCl Series (Gms)					CaCl ₂ Series (Gms)			
Osmotic Concentration	0.5	1.5	2.5	3.5	4.5		1.5	2.5	3.5	4.5
<i>Green Weights</i>										
Blades.....	33.9	30.5	24.1	20.9	13.8	28.6	26.1	16.9	14.0	
Stem + petioles...	17.7	14.9	12.2	8.7	6.2	13.6	11.2	7.4	5.7	
Tops.....	51.6	45.4	36.3	29.6	20.0	42.2	37.3	24.3	19.7	
Root.....	22.2	21.3	18.5	14.2	10.8	16.2	13.9	9.1	8.1	
Whole plant.....	73.8	66.7	54.8	43.8	30.8	58.4	51.2	33.4	27.8	
Top/Root Ratio...	2.3	2.1	2.0	2.1	1.9	2.6	2.7	2.7	2.4	
<i>Dry Matter as Per Cent of Green Weight</i>										
Blades.....	10.94	10.62	10.88	10.12	10.96	10.96	10.36	10.95	11.29	
Stem + petioles...	8.85	9.34	9.87	10.44	11.05	9.98	10.43	11.04	11.62	
Tops.....	10.23	10.19	10.52	10.20	11.00	10.62	10.35	10.96	11.37	
Root.....	5.45	5.32	5.24	5.20	5.32	6.16	6.66	6.62	6.71	
Whole plant.....	8.79	8.53	8.74	8.58	9.03	9.38	9.35	9.76	10.00	

¹Contribution from the United States Regional Salinity Laboratory, Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the eleven western states, and the Territory of Hawaii.

Growth reductions for the whole plants were practically linear with increments in osmotic concentration of the added salt. The green weights of the calcium chloride series of plants (tops and roots) was constantly lower than those of the sodium chloride series. Yet for a given osmotic concentration there appeared to be no significant difference in the green weight of the tops of the two series of plants at respective osmotic concentrations. The differences in weight between parallel observations of the two series for whole plants was due mainly to a consistently large differential in the weights of roots. There were no visual differences in the appearance and quality of growth between the calcium and sodium plants at equal osmotic concentrations. With increasing salt concentration there was a tendency in both series for the leaves to become smaller and to have a deeper green color. These characteristics are similar to those usually associated with xeromorphism.

The roots in the calcium chloride series were consistently smaller than those in the sodium series and this is further reflected in the relatively high top-root ratios for the calcium series.

The percentage dry matter in the leaves of both series of plants showed little consistent trend with treatment. Leaves from some salt treatments were found to be more succulent than those from the base nutrient treatment. In contrast, the stems and petioles showed consistent increases in percentage dry matter with increase in osmotic concentration of the substrate — the calcium chloride series of plants having higher percentages of dry matter than the sodium chloride series. In view of the fact that an increase in osmotic concentration of the substrate restricts water absorption (2, 4) such a trend would be expected. Such small and negligible changes as have been noted in the percentage dry matter of these plants within a series are unquestionably contingent upon the fact that the experiment was carried out in December when temperatures in the experimental greenhouse were relatively moderate, and normal light was at the annual minimum. However, the data is pertinent to field conditions because production of most crops in saline regions of the southwest is most successful during the winter months.

It is striking that the roots of the plants in the calcium chloride series had a consistently higher percentage of dry matter than those of the sodium chloride series, although there was little change with osmotic concentration within a series. It was pointed out previously (3) that most of the sodium absorbed by the plants in the sodium chloride series was localized in the roots. It is possible that the presence of appreciable amounts of sodium in these roots as contrasted with accumulations of calcium in the roots of the other series has accounted for a higher degree of hydration of the protoplasmic constituents. Such a condition would be in complete agreement with the usually observed effect of sodium and calcium upon colloidal systems.

The composition of these plants with respect to certain biochemical constituents is shown in Table II. A study of the inorganic constituents of these plants brought out the fact that increasing increments of salts in the substrate caused a marked decrease in the

TABLE II—NITROGEN AND CARBOHYDRATE FRACTIONS OF BEAN PLANTS AS INFLUENCED BY VARIOUS CONCENTRATION OF ADDED SALTS IN THE NUTRIENT SOLUTION (GREEN WEIGHT BASIS)

Osmotic Concentration	Base Nutrient (Per Cent)	NaCl Series (Per Cent)					CaCl ₂ Series (Per Cent)			
	0.5	1.5	2.5	3.5	4.5	1.5	2.5	3.5	4.5	
<i>Leaves</i>										
Total assimilated N.....	0.488	0.470	0.466	0.427	0.436	0.458	0.439	0.414	0.403	
Protein N.....	0.392	0.361	0.360	0.326	0.335	0.373	0.346	0.322	0.308	
Soluble organic N.....	0.096	0.109	0.103	0.101	0.101	0.090	0.093	0.092	0.095	
Nitrate N.....	0.079	0.051	0.039	0.037	0.024	0.048	0.034	0.026	0.025	
Reducing sugars.....	0.066	0.091	0.099	0.111	0.128	0.094	0.110	0.120	0.145	
Sucrose.....	0.142	0.217	0.241	0.223	0.242	0.296	0.151	0.222	0.195	
Total sugars.....	0.207	0.308	0.340	0.334	0.371	0.390	0.261	0.348	0.340	
Starch + dextrins.....	0.389	0.296	0.350	0.385	0.375	0.274	0.206	0.177	0.339	
Total carbohydrate.....	0.597	0.604	0.690	0.719	0.745	0.664	0.467	0.525	0.679	
<i>Stems</i>										
Total assimilated N.....	0.181	0.194	0.206	0.198	0.197	0.213	0.209	—	0.200	
Protein N.....	0.099	0.120	0.126	0.111	0.109	0.133	0.135	—	0.128	
Soluble organic N.....	0.081	0.074	0.080	0.088	0.087	0.080	0.074	—	0.072	
Nitrate N.....	0.077	0.059	0.060	0.060	0.062	0.061	0.058	—	0.058	
Reducing sugars.....	0.122	0.116	0.111	0.153	0.155	0.149	0.163	—	0.203	
Sucrose.....	0.252	0.260	0.298	0.324	0.362	0.204	0.250	—	0.239	
Total sugars.....	0.373	0.375	0.409	0.477	0.518	0.413	0.413	—	0.442	
Starch + dextrins.....	0.268	0.168	0.259	0.376	0.370	0.238	0.246	—	0.316	
Total carbohydrate.....	0.641	0.544	0.668	0.853	0.888	0.651	0.659	—	0.758	
<i>Roots</i>										
Total assimilated N.....	0.154	0.148	0.134	0.126	0.128	0.160	0.176	0.167	0.166	
Protein N.....	0.120	0.116	0.101	0.096	0.098	0.134	0.150	0.144	0.140	
Soluble organic N.....	0.033	0.032	0.032	0.030	0.030	0.027	0.027	0.023	0.025	
Nitrate N.....	0.060	0.044	0.049	0.043	0.047	0.049	0.046	0.044	0.042	
Reducing sugars.....	0.033	0.037	0.036	0.041	0.040	0.036	0.041	0.040	0.052	
Sucrose.....	0.065	0.069	0.060	0.131	0.116	0.065	0.078	0.093	0.092	
Total sugars.....	0.098	0.102	0.096	0.172	0.157	0.101	0.119	0.133	0.144	
Starch + dextrins.....	0.005	0.027	0.030	0.040	0.026	0.002	0.023	0.024	0.027	
Total carbohydrate.....	0.102	0.132	0.126	0.212	0.182	0.103	0.142	0.157	0.171	

percentage of total nitrogen present in the various portions of the plants, and that the relative amount of nitrogen in the calcium chloride plants was appreciably less than in the sodium chloride plants. Data in Table II show that the amount of unassimilated nitrogen, which had accumulated in these plants prior to utilization, was definitely decreased by the presence of added salt in the substrate. The leaves showed a continual diminution of nitrate content with increasing osmotic concentrations. Although the stems and roots contained less nitrate in the presence of any amount of added salt in nutrient solutions than those from the base nutrient treatment, the salt concentration had practically no effect on nitrate percentages. When these results are interpreted in view of the fact that growth was markedly inhibited by salt increments, it is evident that the absolute amount of nitrate absorbed by these plants had been considerably decreased by the presence of the salts. Although the amount of nitrate in a plant is an index of the reserve of unassimilated nitrogen available for metabolic processes, the soluble organic component serves as a more valid index of the status of nitrogen metabolism. Data in Table II show that there were few marked trends in the soluble organic nitrogen fraction for any of the parts of these plants as conditioned by osmotic concentration of the growing medium. Yet, in each tissue, there appears a consistently

higher proportion of soluble organic nitrogen in the plants of sodium chloride series than in those of the calcium chloride series. It is true that the differences were not large, but their consistency tends to enhance their validity. It is possible that these differences are related to the tendency of the calcium ion to be less conducive to hydration than the sodium ion, accounting for the lower proportion of simpler nitrogenous compounds in the calcium plants. This is shown in Table III.

TABLE III—PROTEIN AND SOLUBLE ORGANIC NITROGEN IN BEAN PLANTS AS PROPORTIONS OF TOTAL ASSIMILATED NITROGEN

	Base Nutrient (Per Cent)	NaCl Series (Per Cent)					CaCl ₂ Series (Per Cent)			
Osmotic Concentration	0.5	1.5	2.5	3.5	4.5		1.5	2.5	3.5	4.5
<i>Leaves</i>										
Protein as per cent of total assimilated N.....	80.3	76.8	77.3	76.3	76.8		81.4	78.8	77.8	76.4
Soluble organic as per cent of total assimilated N....	19.7	23.2	22.7	23.7	23.2		19.6	21.2	22.2	23.6
<i>Stems</i>										
Protein as per cent of total assimilated N.....	54.7	61.9	61.2	56.1	55.3		62.4	64.6	—	64.0
Soluble organic as per cent of total assimilated N....	44.8	38.1	38.8	43.9	44.7		37.6	35.4	—	36.0
<i>Roots</i>										
Protein as per cent of total assimilated N.....	77.9	78.4	75.4	76.2	76.6		83.8	85.2	86.2	84.3
Soluble organic as per cent of total assimilated N....	21.1	21.6	24.6	23.8	23.4		16.2	14.8	13.8	15.7

One might expect that increasing hydrostatic stress would be conducive to condensation of simple nitrogenous compounds to complex proteins. Nightingale and Farnham (4) observed this to be the case. The present data show that the amount of protein in the leaves, which are the main reservoir of protein in these plants, was decreased by successive increments of salt in the substrate. It is to be recalled that Nightingale and Farnham (4) increased osmotic concentration by uniformly increasing the concentration of all salts in the base nutrient solution so that nitrogen supply and relative absorption was greatly increased in their plants. The added salts not only inhibited nitrogen absorption in the present study, but also the amount of protein in the leaves, both as percentage composition of the leaves and as a proportion of the total assimilated nitrogen therein. In the stems and roots it is pertinent that the assimilated nitrogen contained a higher proportion of protein nitrogen within the calcium chloride plants than in the sodium chloride plants. And, accordingly, the soluble organic nitrogen relationship was just the reverse. The specific effect of the calcium and sodium ions on colloidal systems coincides with these observed shifts in metabolic constituents. It should be stressed that this effect was largely in the roots, and that the growth data showing differentials between the calcium and sodium series of plants are

undoubtedly largely related to this differential in the metabolic status of the roots.

The data for the carbohydrate fractions in the plants emphasized mainly that the aerial environment under which these plants were grown caused plants in all treatments to be relatively very low in all carbohydrate components, especially starch. There was a general tendency for sugar to accumulate with increasing osmotic concentration of the substrate; whereas, the observations on starch were rather erratic, showing no accumulation with added salt, but actually a marked decrease in the amount of starch in the plants at the low salt concentrations. Such accumulation of sugars may well have been anticipated. They would be largely responsible for an increase in the osmotic value of the tissues of these plants; for such an increase may have been reasonably expected to accrue from an increase in osmotic concentration of the substrate.

SUMMARY

Growth of red kidney bean plants as measured by green weight showed a linear decrease with increasing increments in osmotic concentration of the substrate. Plants in the calcium chloride series made consistently less growth than in the sodium chloride series and the difference was largely due to poorer root growth in the calcium series. Consequently the top root ratios were appreciably higher in the latter series.

Increments of added salts in the substrate were associated with decreases in the percentage of nitrate nitrogen in the plants. Salt concentrations *per se* did not modify the percentage of soluble nitrogen in the plants, but the values were consistently higher in the sodium chloride series than in the calcium chloride series of plants. Percentage of protein diminished with increments of added salt. Protein nitrogen constituted a much higher proportion of the assimilated nitrogen in the stems and roots of the calcium chloride series of plants. It was suggested that the differential effects of Na^+ and Ca^{++} ions on hydration of colloids may be involved and the results obtained are in complete agreement with such known effects.

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The Influence of Saline Substrates upon the Absorption of Nutrients by Bean Plants¹

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SODIUM and calcium salts are the main components of saline accumulations in the irrigable lands of the western states. Soils investigators know that these two cations have very diverse effects upon the physical characteristics of soils. In addition to the differential influence of various salts upon the physical condition of soils and the resultant effect upon plant response, salt accumulations *per se* in the soil solution have a direct effect upon the growth of plants. In order to better evaluate the specific factors in saline soils contributing to the integrated plant responses, it became expedient to ascertain first of all the responses of the test plant to saline stresses uncomplicated by the more elusive contingencies induced by soil colloids. It is interesting to note in this connection, however, that Collander (1) and others, have observed that in a comparison of plants grown in solution culture and in soil, most of the peculiarities in cation selection were unaltered. When the proportionality of cations in plants grown in soil deviated from that of plants grown in solution, the relative unavailability (assuming no deficiency in the soil) of certain cations was indicated.

Dwarf red kidney bean plants, from the early seedling stage to the time of incipient flowering, were subjected to serial concentrations of added salts in aerated solution culture. The type of solution culture equipment used has been described by Eaton (2). The added salt in



FIG. 1. General appearance of bean plants at time of harvest. (Base nutrient—0.5 atmosphere osmotic concentration; 1, 2, 3, and 4—atmospheres osmotic concentration of added salt).

¹Contribution from the United States Regional Salinity Laboratory, Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the eleven western states, and the Territory of Hawaii.

one series was NaCl, and in the other, calcium chloride. In addition to the base nutrient culture (0.5 atmosphere osmotic concentration), there were four salt levels of 1, 2, 3, and 4 atmospheres osmotic concentration of added salt over and above the base nutrient solution. There were four plants per culture, and treatments were thrice-replicated and randomized within the greenhouse. Each culture contained 13 liters of solution which was adjusted to volume daily with distilled water. Frequent additions of small amounts of 1-N HCl were added to the substrate to maintain the pH between 5.5 and 6.5.

During the 32 days of growth (from the start of germination until harvest) no diagnostic leaf or other symptoms appeared in either set of plants. There was, however, a reduction in size of plant in direct relation to intensity of salt concentration (Fig. 1). Average dry weights of the plants are given in Table I. The stems and petioles (B) and

TABLE I.—AVERAGE DRY WEIGHTS OF BEAN PLANTS AS INFLUENCED BY INCREMENTS OF NaCl AND CaCl₂ IN THE SUBSTRATE

Osmotic Concentration	Base Nutrient (Gms)	NaCl Series (Gms)					CaCl ₂ Series (Gms)			
		0.5	1.5	2.5	3.5	4.5	1.5	2.5	3.5	4.5
(A) Leaf blades.....	3.71	3.24	2.62	2.11	1.52	3.13	2.70	1.85	1.58	
(B) Stems + petioles.....	1.57	1.39	1.20	0.91	0.68	1.35	1.16	0.81	0.66	
(C) Tops (A + B).....	5.28	4.63	3.82	3.02	2.20	4.48	3.86	2.66	2.24	
(D) Roots.....	1.21	1.13	0.97	0.74	0.58	1.00	0.93	0.60	0.54	
Whole plant (C + D).....	6.49	5.76	4.79	3.76	2.78	5.48	4.79	3.26	2.78	

roots (D) of the NaCl series of plants consistently, though slightly, exceeded in weight those of the CaCl₂ series. The actual total dry weight and the reduction in weight of whole plants, however, was very similar in both series. It is readily apparent (Table I) that for both series there is a linear relationship between osmotic concentration of the substrate and reduction in dry weight of the whole plants.

Despite the fact that the general appearance of the plants and the growth reduction by salt increments were so similar in the two series, there were some very significant differences in the concentration, absolute amount, and distribution of Ca, Na, K, Cl, P, and total-N within the plant and, as is discussed in a later paper (6), differences in the proportions of various nitrogen fractions. As is shown in Table II increases in the concentrations of Ca, Na, and Cl in the substrate were associated with increasing concentrations of these respective elements in the plants. With the exception of specific cation effects (Na *vs.* Ca) on the *relative levels* of P and K within the plants of the two series, increases in concentration of either added salt (NaCl or CaCl₂) in the substrate had little consistent effect on the *concentration* of P and K in the plants. However, increases in amount of either added salt in the substrate did result in a serial decrease in the N content.

It was the primary aim of this study to ascertain whether or not the prevalence of excess of Ca *vs.* Na salt in the growing medium had a

TABLE II—COMPOSITION OF BEAN PLANTS AS INFLUENCED BY INCREMENTS OF NaCl AND CaCl₂ IN THE SUBSTRATE (DRY WEIGHT BASIS)

Treatment	Milliequivalents per Kilo of Dry Matter					
	Ca	Na	K	Cl	PO ₄	Total-N
<i>Leaves</i>						
Base nutrient.....	1826	21	946	56	833	3700
Base nutrient + 1 NaCl	1850	26	1057	451	828	3510
Base nutrient + 2 NaCl	1911	42	1047	760	780	3510
Base nutrient + 3 NaCl	2017	50	1088	1064	768	3280
Base nutrient + 4 NaCl	1990	52	1037	1302	773	3000
Base nutrient + 1 CaCl ₂	2830	—	776	638	753	3300
Base nutrient + 2 CaCl ₂	2991	—	777	1034	702	3260
Base nutrient + 3 CaCl ₂	3056	—	738	1305	667	2870
Base nutrient + 4 CaCl ₂	2996	—	622	1599	538	2710
<i>Stems</i>						
Base nutrient.....	612	64	1708	123	653	2080
Base nutrient + 1 NaCl	605	91	1878	412	651	1935
Base nutrient + 2 NaCl	598	175	1879	545	666	1930
Base nutrient + 3 NaCl	600	229	1732	535	583	1764
Base nutrient + 4 NaCl	722	388	1695	671	502	1671
Base nutrient + 1 CaCl ₂	1001	—	1613	466	637	1972
Base nutrient + 2 CaCl ₂	1130	—	1573	651	564	1830
Base nutrient + 3 CaCl ₂	—	—	—	—	—	—
Base nutrient + 4 CaCl ₂	1362	—	1419	893	563	1588
<i>Roots</i>						
Base nutrient.....	417	85	1625	118	1859	2800
Base nutrient + 1 NaCl	326	555	1350	631	1708	2572
Base nutrient + 2 NaCl	342	1101	1222	872	1722	2495
Base nutrient + 3 NaCl	335	1406	945	893	1620	2318
Base nutrient + 4 NaCl	359	1558	990	949	1868	2350
Base nutrient + 1 CaCl ₂	783	—	1479	613	1951	2430
Base nutrient + 2 CaCl ₂	760	—	1245	633	1612	2387
Base nutrient + 3 CaCl ₂	—	—	—	—	—	—
Base nutrient + 4 CaCl ₂	824	—	1455	733	1912	2208

differential effect upon the absorptive availability of the primary fertilizer components, N; P, and K, when the amounts of these elements present in the nutrient solution were uniform. In a comparison of absolute amounts of N-P-K absorbed, with but few exceptions, at each respective level of salt there was more N and P in the leaves, stems, and roots of the NaCl series than in the CaCl₂ series. There was a very similar distribution of the N and P within the control and NaCl and CaCl₂ series of plants. Similarly at each respective level of salt there tended to be a higher total amount of K in the leaves, stems, and roots of the NaCl series than in the CaCl₂ series. Also there was a marked difference in the distribution of K within the plants of the two series. With approximately equal percentages of the total K in stems, the leaves of the NaCl series contained 19 per cent more and the roots 29 per cent less of the total amount of K in the plants than did these same plant parts in the CaCl₂ plants. These increases in total amounts of N, P, and K absorbed by the NaCl plants as compared with the CaCl₂ plants are in agreement with and of interest in connection with the work of Osterhout (4) and that of True and Bartlett (5) which demonstrated an increase of permeability to salts associated with Na and a decrease in permeability with calcium.

These differences in N, P, and K absorption should be further interpreted in the light of the variations in absorption of Ca, Na, and Cl among these series of plants. Although Ca and Cl concentrations in

the various portions of the plants were commensurate with the concentrations of these ions in the respective substrate, the percentage of Na in these plants as affected by concentration of Na in the nutrient solution presented a striking contrast to that observed for these two ions. There was practically no Na accumulation in the leaves, small amount in the stems, but a very large amount in the roots as a result of increasing Na concentrations in the substrate. On an absolute basis Na was distributed nearly equally among the leaves, stems, and roots in the control plants, but throughout the NaCl series approximately 74 per cent of the total Na absorbed was in the roots, 18 per cent in the stems, and only 8 per cent in the leaves. Thus on an amount per plant basis there was only 5.5 per cent more Na in the leaves of the plants receiving a one atmosphere addition of NaCl but 526.0 per cent more in the roots of these cultures than in the analogous tissues of the control plants. The question arose concerning the mechanism by which such an ion as Na may be held so exclusively in the roots, but the present study offered no satisfactory explanation. Another striking observation, however, was that the concentration of Ca in the leaves, stems, and roots of the NaCl plants remained nearly uniform throughout the series and equal to that found in the control plants even though the mass action phenomena in the substrate would have tended to inhibit this absorption of calcium. Assuming that Cl *per se* may accumulate in toxic concentrations in leaves, it is noteworthy that in this experiment with serial increases in the concentration of Cl in the substrate, there were successively increasing proportions of the total Cl in the leaves and decreasing proportions of the total in the stems and roots. Although the proportion of total Cl in the stems was nearly the same in both series, there was a higher percentage of the total in the leaves and a smaller percentage in the roots of the CaCl₂ series of plants than in the NaCl series. Inasmuch as a stoichiometrical balance of ions must exist in the plant system the accumulation of Cl, without a corresponding accumulation of Na in the leaves of the NaCl series, must have been equalled by the absorption of some other cation. The trend toward increased basicity of the substrate suggested that primarily hydrogen ions were absorbed to effect this balance. Eaton (3) reported that the pH of the expressed sap is usually lower in high-chloride plants than in the control plants.

SUMMARY

Despite the similarity in appearance of the bean plants grown in serial, high osmotic concentrations of NaCl and CaCl₂, there were marked differences in total absorption and distribution of the basic nutrient elements, N-P-K, as well as of Na and calcium. In both series of plants the concentration of Ca greatly predominated over that of Na in the leaves and stems, while in the NaCl series the roots were relatively high in Na and in the CaCl₂ series relatively high in calcium. Larger total amounts of N, P, and K were absorbed by the NaCl plants, in which Na predominated in the roots, than by the CaCl₂ plants. The inverse effect of Na *vs.* Ca on permeability of cells to salts is considered a major factor.

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The Effect of Storage on the Betanin and Sucrose Content of Garden Beets (*Beta vulgaris*) and its Importance in a Breeding Program with This Crop

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A COMMON belief among canners is that when beets are stored in the fall for a period of 1 to 4 weeks, the quality of the beet improves. By improvement of color they usually mean that the white zones are less distinct, or that there is a more even distribution of the color in the roots. They may also think that there is actually more pigment present. This belief has had a collary which also needs varification; namely, that the pigment which increased during storage, did so at the expense of the sugars. The truth or falsity of these hypotheses is of prime importance to the plant breeder when he is selecting a beet which must be of high quality at the time of harvest. Naturally, he is unable to make his selections all within a day or so. If the beet undergoes a change of sucrose into pigment the plant breeder may easily make the mistake of selecting a beet which apparently is high in pigment but actually had little pigment some weeks before.

The object of this study was to determine whether or not the betanin and sucrose content of garden beets do undergo changes during storage and to what extent. If these compounds fluctuate in individual roots in storage that are being used in genetical studies and in crop improvement the geneticist must make allowances for these complicating physiological reactions and exercise great care in selecting mother roots.

This study is a part of a more extensive investigation on the influence of environmental factors, soil nutrients, soil type, season, time of harvest, and geographical location, on the betanin and sucrose content of garden beets. All of these problems are involved and interrelated in a successful breeding program with this crop.

MATERIALS AND METHODS

In the fall of 1939 a pilot experiment on storage was undertaken. The seed, Asgrow Canner M3520, was sown on July 26 and the roots were dug on September 30. At the time of harvesting all the beets were washed and their tops trimmed to $\frac{1}{4}$ inch in length. One hundred and thirty roots, each weighing approximately 100 grams, were selected, divided into 13 lots of 10 roots each, and dipped in water soluble wax. They were then bagged and sent to Ithaca where they were placed in the cold storage rooms of the Vegetable Crops Department of Cornell University. There was a lapse of 4 days between digging and storage. Three lots were put in each of four rooms which were kept at 35 degrees F, 40 degrees F and 50 degrees F. One lot from each room was removed at the end of 2 weeks, at 4 weeks, and the rest at the end of 8 weeks. The thirteenth lot at the time of harvest had been dried immediately for analysis.

As each lot was removed from storage, the roots were weighed and

grated, well mixed, and a 150 gram aliquot was dried for analysis. The determination of sucrose was made according to the Shaffer Somogyi (1) method and reagent No. 50 as modified by Somogyi (2) was used. In these storage experiments all sugars were calculated as sucrose, since, in former analyses both with freshly harvested and stored roots, only 1 to 3 per cent of reducing sugars were found. Betanin determinations were made according to the method developed by Pucher, Curtis, and Vickery (3, 4) in connection with this study.

Roots of the same strain, Asgrow Canner M3520, were grown in the spring of 1940. Seed was planted on April 29; roots were harvested on July 15. From this crop 700 roots of approximately the same size and weight were selected. These were divided into 70 groups of 10 roots each. They were prepared for storage in precisely the same manner as described in the pilot experiment.

Sixty groups were then placed in storage at 40 degrees F at the Boyce Thompson Institute of Plant Research, Yonkers, New York. Ten groups were dried immediately at the time of harvest for analysis. The remaining 60 groups were withdrawn in lots of 10 groups each at the end of 2, 6, 12, 21 and 30 weeks. Less than 24 hours elapsed between the time the roots were dug and the time that they were placed in the storage chamber.

The preparation for analysis was identical with that described for the pilot experiment. Drying was done in a ventilated oven with air circulation at 81 degrees C for about 1½ hours. Rough dry weights and final dry weights were made. Betanin and sucrose were determined. The data were analyzed by Fisher's (5) method of analysis of variance and covariance.

DISCUSSION

When the results (Tables I and II) of these two experiments are compared, they are found to differ widely. In the pilot experiment, the

TABLE I—DRY WEIGHT, BETANIN, AND SUCROSE CONTENT OF FALL GROWN BEETS AT THE TIME OF HARVEST, AND AT THE END OF STORAGE PERIODS AND TEMPERATURES INDICATED. ALL CALCULATIONS ARE BASED ON GRAMS OF MATERIAL PER KILOGRAM OF FRESH TISSUE. EACH VALUE IS BASED ON ONLY ONE SAMPLE OF TEN ROOTS

	35 Degrees F			40 Degrees F			50 Degrees F		
	Dry Weight	Betanin	Sucrose	Dry Weight	Betanin	Sucrose	Dry Weight	Betanin	Sucrose
At time of harvest.....	112	1.47	45.8	112	1.47	45.8	112	1.47	45.8
2 weeks.....	112	0.85	52.5	111	0.64	52.0	106	0.80	54.0
4 weeks.....	108	0.98	50.7	103	0.90	49.0	85.8	0.97	41.6
8 weeks.....	107	1.08	52.5	109	1.21	48.0	93.9	0.97	40.3

sugar content of all lots of beets placed in storage at different temperatures for different lengths of time increased for the first 2 weeks and then decreased. The betanin, on the contrary, decreased sharply during the first 2 weeks and then increased gradually (Figs. 1 and 2).

In the second experiment there were no significant increases of sucrose above the original samples. In fact the sucrose diminished gradually up to 21 weeks after which there was an appreciable drop.

TABLE II—THE COMPARISON OF THE DRY WEIGHT, BETANIN, AND SUCROSE CONTENT OF SPRING GROWN BEETS HELD IN STORAGE FOR 2, 6, 12, 21, AND 30 WEEKS AT 40 DEGREES F. EACH VALUE IS THE MEAN OF TEN SAMPLES

	Dry Weight (Grams Per Kilograms of Fresh Weight)	Betanin (Grams Per Kilograms of Fresh Weight)	Sucrose (Grams Per Kilograms of Fresh Weight)
Original.....	122.73 \pm 0.915	0.826 \pm 0.034	62.57 \pm 0.62
2 weeks.....	120.01 \pm 1.10	1.05 \pm 0.028	63.41 \pm 1.05
6 weeks.....	116.2 \pm 1.04	1.016 \pm 0.021	59.91 \pm 1.09
12 weeks.....	112.38 \pm 0.97	0.809 \pm 0.016	58.22 \pm 0.51
21 weeks.....	103.08 \pm 1.05	0.920 \pm 0.029	47.47 \pm 1.12
30 weeks.....	92.15 \pm 1.88	0.577 \pm 0.017	33.46 \pm 1.64

The dry weight followed a gradual decline with significant changes occurring at each sampling date except at the second week. There

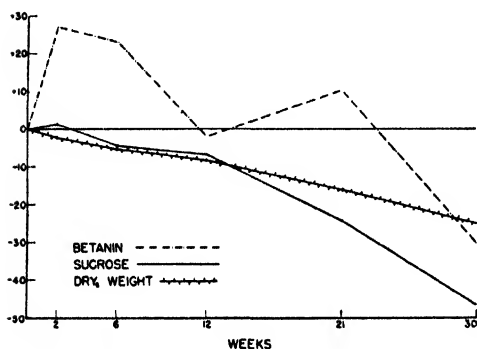


FIG. 1. Shows the per cent change of betanin, sucrose and dry weight of the spring crop held in storage at 40 degrees F.

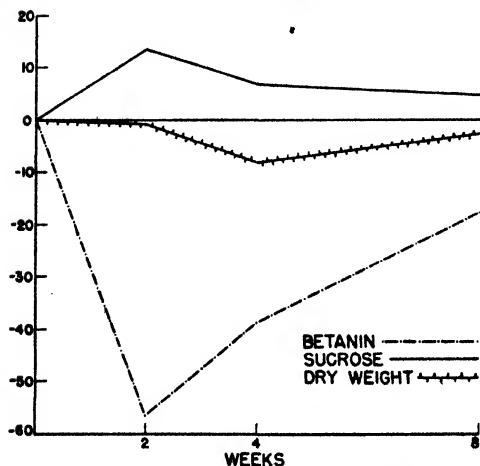


FIG. 2. Shows the per cent change of betanin, sucrose and dry weight of the fall grown crop held at 40 degrees F.

was a significant increase of betanin content in the second and sixth week samples and at the twelfth week a significant drop. In short, there was, in the betanin content, a significant change from the original at every sampling date except at the twelfth week period. At this time the betanin was probably diminishing from a previous increase and had reached the original content.

The results of the analysis of variance of the data obtained in the experiment with the spring crop are presented in Table III.

The F values indicate that highly significant differences exist between the mean values for periods of storage of dry weight, sucrose and betanin. These mean values are presented in Table I together with their standard error.

The analysis of covariance was carried out to determine the relationship between dry weight, sucrose and betanin. The

TABLE III—ANALYSIS OF VARIANCE OF DATA OBTAINED WITH THE SPRING CROP STORED AT 40 DEGREES F FOR DIFFERENT PERIODS OF TIME

Source of Variance	D.F.	Mean Squares		
		Dry Weight	Sucrose	Betanin
Between periods.....	5	1389.7	1340.9	0.1828
Within periods.....	51	14.0	15.8	0.0046

correlation between both betanin and sucrose and dry weight is positive and highly significant. The correlation between betanin and sucrose is not significant between periods but within periods it is positive and significant. Since both betanin and sucrose are highly correlated with dry weight the removal of the latter as a factor influencing the relationship between betanin and sucrose does not add to the significance between samples within periods.

The fact that these two sets of experiments do not agree does not necessarily need to be explained in this report. The results show that the betanin in the garden beet is extremely sensitive to the conditions of storage and that it may increase or decrease in amounts during the storage period. These results establish the fact that more extensive experimentation should be conducted to learn more about the factors or group of factors which are responsible for the fluctuations in betanin content.

Although the technique was identical, there were various contributing factors which doubtless influenced the materials, thereby causing a variance in the results. The pilot experiment made use of a fall grown crop; the second experiment used a spring crop.

An examination of Tables I and II shows that the initial betanin and sucrose content of these two crops of roots differed considerably. The betanin content of the first group was 1.47 whereas that of the spring crops was .826 grams per kilo of fresh weight. The sucrose content of the fall crop was much lower than that of the spring crop. These values are 45.8 and 62.57 grams per kilo of fresh weight for the fall and spring crops, respectively.

It is to be expected that two sets of experimental material grown in two different seasons of two different years would have a different initial composition and might therefore react differently when subjected to experimentation. For this reason the two experiments are not entirely comparable.

Another contributing factor was that storage conditions were different for the two experiments. Different plant materials were stored in each chamber, respiration products from these materials together with probable contributory differences in humidity might have been the responsible factors.

Perhaps, too, the discrepancy in results may be explained by the fact that in the pilot experiment only one sample of the 10 roots was available for each analysis, whereas in the second experiment 10 samples of 10 roots each were used. The results of the second experiment are statistically more reliable.

SUMMARY AND CONCLUSIONS

Experimental results are presented which show that the betanin and sucrose content of spring grown beet roots used in this experiment undergo significant changes when subjected to storage for different periods of time at 40 degrees F. Inconclusive, although highly indicative results are presented which show that the betanin and sucrose content of fall grown beet roots used in this study also undergo changes when stored at different temperatures for different periods of time.

This information is important to the plant breeder in his program of selecting mother roots high in these compounds, using absolute values as the basis of his selection. For example, if he finds that a particular progeny has a low betanin or sucrose content in the spring, after having been stored over winter, he may discard it entirely, whereas this same progeny may have had a high betanin content at the time of harvest. Conversely he may select a highly pigmented root at some time subsequent to harvest when this same root might have had little pigment at the time of harvest. The objective of the plant breeder is to select mother roots that will transmit to their progeny the ability to produce the maximum betanin and sucrose at the time of harvest. It is logical to conclude that this objective can best be attained by selecting mother roots at the time of harvest when these compounds are present in amounts which determine their commercial value rather than at some subsequent time when they have changed in the storage process.

The normal practice is for seedsmen in the spring to select mother beet roots which were grown the preceding fall and were stored all winter. According to the data presented here, the betanin content of fall grown beets, when subjected to storage, fluctuates appreciably and the sucrose content increases for the first 2 weeks and then diminishes steadily during the storage period. Consequently, plant breeders who follow the practice of spring selections on fall grown roots may be easily misled in their judgement.

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Some Effects of Calcium and Nitrogen Upon Peas¹

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THE extent to which garden peas carry on their symbiotic relationship with nitrogen fixing organisms is of considerable importance and interest to vegetable growers. It is usually recommended that peas should be inoculated if they are to be planted upon soil about which there is some question as to the presence of nodulating organisms. However, that inoculation is not always equally beneficial is rather universally accepted.

The importance of soil fertility in the nodulation of soybeans has been demonstrated by Albrecht (1) and Graham (2). They have shown that as the exchangeable Ca (1) and the exchangeable Mg (2) were increased the total amount of nitrogen fixation also was increased.

In an attempt to study the influence of soil fertility upon the growth, nodulation, and Ca content of garden peas, controlled soil treatments were set up in which the Ca and N contents were varied according to the following procedure.

METHOD AND PROCEDURE

Peas² of the Little Marvel variety, especially selected for varietal purity were used. The plants were grown in 1-gallon glazed stone jars and thinned soon after germination to three plants per jar. There was a total of 20 jars in each of 5 Ca levels, 10 of which were supplied with 4 milliequivalents of N, and 10 received 12 milliequivalents of N. One-half of the jars (five) at each N level were inoculated and one-half were not. Inoculation was made at two different times. The first at seeding and the second when the plants were approximately 2 inches in height. The seeds were planted December 1, 1940 and the plants harvested February 22, 1941.

For a medium the desired amounts of plant nutrients were added directly to previously determined quantities of clay from the subsoil of the Putman silt loam. The clay was then mixed with definite amounts of white quartz sand to give a suitable sandy texture. This Beidellite clay has an exchange capacity of roughly 28 milliequivalents per 100 grams of subsoil. Twelve of these are Ca and 12 are H. The clay also has present upon it small quantities of minor elements so that it is unnecessary to include them in the nutrients added.

The quantity of all the nutrients added excepting Ca and N was constant for all of the treatments. The amounts added per jar were potassium 9 M. E., phosphate 9 M. E., magnesium 2 M. E., and sulfate 2 M. E.

Calcium was supplied in varying amounts to give five different levels. The amounts added, per jar, to the quantity originally on the subsoil were 0, 2, 6, 12, and 24 M. E.'s.

Nitrogen was applied at two levels to each of the five Ca levels. The

¹Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station Journal Series No. 797.

²Courtesy of the Associated Seed Growers.

quantities of N applied were 4 and 12 M. E. Ammonium nitrate was the sole source of N for both treatments.

RESULTS AND DISCUSSION

That the nodulation of garden peas was increased as the exchangeable Ca in the soil was increased is demonstrated by the data, Table I. This increase in symbiotic activity occurred at both levels of N. Where 4 M. E. of N was applied, the nodule count for the treatments to which

TABLE I—EFFECT OF CA AND N UPON THE GROWTH, NODULATION, AND CA CONTENT OF PEAS

M. E. of Calcium Applied	Inoculated or Uninoculated	M. E. of Nitrogen Applied	Dry Weight (Gms)	Total Number of Nodules	Percentage of Calcium in Tops	Total Calcium (Mgs) in Tops
0	Inoculated	4	8.30	88	1.96	183
		12	20.70	212	1.86	386
	Not Inoculated	4	5.70	0	1.69	96
		12	15.30	0	2.23	342
2	Inoculated	4	13.60	243	2.18	296
		12	21.50	341	2.41	519
	Not Inoculated	4	10.10	0	2.47	250
		12	16.40	0	2.33	383
6	Inoculated	4	16.20	385	2.43	394
		12	23.90	518	2.69	642
	Not Inoculated	4	11.70	0	2.74	321
		12	22.30	0	2.35	525
12	Inoculated	4	18.70	498	2.86	536
		12	20.20	671	2.72	550
	Not Inoculated	4	11.30	0	3.06	358
		12	21.90	0	3.02	662
24	Inoculated	4	16.40	384	3.33	547
		12	20.70	565	2.84	588
	Not Inoculated	4	10.70	0	4.39	496
		12	18.40	0	3.35	617

0, 2, 6, 12, and 24 M. E. of exchangeable Ca was applied was 88, 243, 385, 498, and 384 respectively. This was a steady increase with each Ca addition with the exception of the treatment where the largest quantity of Ca was applied. This series showed a reduction in nodulation to the level where 6 M. E. were added. Such a depression suggests the possibility of the entrance of some limiting factor other than Ca. With increasing Ca treatments where 12 M. E. of N was supplied there was likewise a steady increase in the nodule count with the exception of the treatment where 24 M. E. of Ca was added which developed fewer nodules than where 12 M. E. were applied.

It is of interest to note that at each Ca level there is a significant increase in the number of nodules produced at the higher than at the lower N levels. A study of the data reveals that increases in nodulation attributed to increased N are equally as great as those resulting from increased Ca application. An examination of the plants in the treatments which had not been inoculated showed that no accidental inoculation had taken place.

The dry weights of the peas showed that inoculation resulted in significant increases in all but one treatment. Where 4 M.E. of N were added there was an increase in dry weight resulting from inoculation

at all Ca applications. The differences between inoculated and uninoculated became greater as the Ca was increased. The total dry weight of all the uninoculated treatments was 49.5 grams while the inoculated totaled 73.2 grams an increase of 47 per cent.

Where 12 M. E. of N were supplied, there was likewise an increase in dry weight resulting from inoculation except where 12 M. E. of Ca was added. The total dry weight of all uninoculated treatments was 94.3 grams while the inoculated treatments weighed 107.0 grams. This was an increase of 13 per cent.

Increasing the Ca up to a certain point gave an increase in dry weight. Beyond this point the total production was depressed by additional Ca. All Ca treatments receiving 12 M. E. of N whether inoculated or not, produced more dry weight than either the inoculated or uninoculated at 4 M. E. of N. The total dry weight of all treatments at 4 M. E. of N was 122.7 grams, while those receiving 12 M. E. weighed 201.3 grams. This represented an increase of 64 per cent.

When the Ca content of tops is considered, it is interesting to note that at both N levels and with both the inoculated and uninoculated plants, the Ca content as percentage increased as additional quantities of the exchangeable Ca were supplied to the soil. The uninoculated treatment receiving 0 M. E. of Ca and 4 M. E. of N contained the lowest percentage Ca (1.68 per cent). The same treatment except that 24 M. E. of Ca was applied gave the highest Ca percentage (4.39 per cent).

On the basis of the total amount (milligrams) of Ca in the crop, it is of significance to note that for both N treatments and with both the inoculated and uninoculated plants there was a marked increase with Ca additions to the soil. The total Ca content of all treatments receiving no additional Ca to that originally on the subsoil was 986.8 milligrams. The total content of similar treatments but receiving 24 M. E. of Ca was 2249.4 milligrams. This represented an increase of well over 100 per cent.

In the Ca treatments to which 4 M. E. of N was applied the total Ca content was consistently higher in the inoculated than in the uninoculated series. This increase as a total of all the Ca treatments was 27 per cent. When 12 M. E. of N was applied, the inoculated plants were higher in total Ca where 0, 2, and 6 M. E. had been supplied. The uninoculated plants were higher where 12 and 24 M. E. of Ca was added to the medium. At all Ca applications, the series receiving 12 M. E. of N had a greater total Ca content than did those receiving 4 M. E. The total of all the treatments receiving 4 M. E. of N was 3.253 grams, while that of those receiving 12 M. E. was 5.215 grams, an increase of 50 per cent.

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Seed Production in *Primula obconica*

By G. A. L. MEHLQUIST, *University of California,
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DURING normal times the main supply of seed of this *Primula*, which is grown in large quantities as a pot plant, has been produced in Europe, mainly in Germany and Switzerland. With the coming of the present war this supply necessarily came to an end. When the growers in this area attempted to produce their own seed they encountered two sorts of difficulties. In the first place, plants selected for seed often failed to produce seed and, secondly, when seed was obtained, it often did not come true to type. This study was therefore undertaken in an effort to relieve this situation.

In *Primula obconica* heterostylism is the rule. That is, some plants have long styles reaching to the upper limit of the throat, whereas the anthers are located very low in the corolla tube. Other plants have short styles not reaching over half way up the tube, whereas the anthers are located high in the throat.

Inasmuch as this structural difference encourages cross pollination by insects rather than self pollination it is reasonable to assume that by selection a condition should eventually arise in which fertility should be greatly influenced by the direction in which the pollination is effected.

Darwin (2) was apparently the first to show experimentally the relation between this structural difference and fertility. He found that pollination between long-styled and short-styled plants resulted in nearly twice as many seeds as pollination among either long-styled or short-styled plants. To emphasize this difference in fertility he termed the combinations long x short and short x long "legitimate" and the combinations long x long and short x short "illegitimate" pollinations. Gregory (6) working with *Primula sinensis* found similar differences. The figures reported by him in terms of average number of seeds per capsule are: long x short = 33, short x long = 25, long x long = 21, and short x short = 11. The results obtained in this study with *P. obconica* are summarized in the Table I.

TABLE I—SEED PRODUCTION IN *PRIMULA OBCONICA*

	1940-41			1941-42		
	Pollina- tions Made	Capsules Matured	Mean No. of Seeds	Pollina- tions Made	Capsules Matured	Mean No. of Seeds
Long selfed.	76	14	0	230	110	1.44
Short selfed.	64	13	0	246	130	1.33
Long x long.	73	11	1.2	143	61	2.31
Short x short.	53	9	0	156	117	1.53
Short x long.	64	55	61.3	54	51	73.7
Long x short.	139	122	85.6	803	745	128.5

As in *Primula sinensis*, long x short here is the most fertile combination and short x short the least fertile. However, not only is the difference in fertility as indicated by these results about six times

greater than that reported by Gregory for *P. sinensis* but the seed production from the "illegitimate" combinations is so low as to be of no practical value.

The results show very definitely that only the "legitimate" combinations will produce seed in sufficient quantity on a commercial basis. Furthermore the circumstance that in the short-style type the pollen is readily accessible, whereas the style cannot be conveniently reached without emasculation or removal of the flowers makes this type best suited as the pollen parent. On the other hand in the long-style type the style is readily accessible for pollination without emasculation, whereas the pollen cannot be reached unless the corolla is pulled off and opened. This makes this type ideally suited as the seed parent. Thus the morphological differences between these two types favor the combination which in both *Primula sinensis* and *P. obconica* has proved to yield the most seed.

Pollination can be effected either by the use of small forceps or a small camel's hair brush. The brush is by far the most effective if a large number of pollinations are to be made. One brush should be used for each pollen plant to avoid contamination. Pollination once a week is sufficient to catch every flower on the seed plant. One pollen plant was found to be enough for five seed plants. One well grown plant if properly pollinated will produce 10,000 or more seeds.

Some of the pollinations were made in mid-winter when practically no insects were around. During the spring months when there was danger of interference from insects two types of protection were tried. On some plants, individual flower clusters were enclosed in small muslin bags equipped with a draw string. Other plants were enclosed in muslin covered cages large enough to cover two to six plants. Equally good seed set was obtained by either of these methods. However, if true to type seed is desired it is obviously safer to keep insects out, and cages are less time consuming than bags.

That insect pollination should not be depended upon is evident from the results obtained from cross pollinating plants of different colors.

Thus red x white and deep pink x white resulted in a very pale pink F_1 , blue x white gave very pale blue. These colors bleached badly in sun light or with higher temperatures and were saleable only if dark, cool weather prevailed. Red x blue gave a very unattractive magenta-purple color. These undesirable F_1 colors make it imperative that, if the seed is intended for production of pot plants under glass, which at best is an expensive operation, all insects large enough to effect pollination be excluded. Cheese cloth or muslin fine enough to keep out insects as large or larger than leaf hoppers is satisfactory. Obviously the method used by many local growers of placing plants of one color in one end of the greenhouse and plants of another color in the other end will not give pure seed especially since in most cases insects are depended upon to do the pollination. If no means for excluding insects are available, hand pollination as suggested should be made during mid-winter.

Normally heterostylism is accompanied by a difference in pollen size. That is, long styled, low-anthered plants have small pollen while

short-styled, high-anthered plants have large pollen. Of the 16 plants with which this study was begun, 9 were short-styled, high-anthered with large pollen and 7 were long-styled, low-anthered with small pollen. Of 518 plants raised from these, 247 were short-styled, high-anthered with large pollen and 271 were long-styled, low-anthered with small pollen. In over 300 plants examined in nearby nurseries the results were the same. Short style, was always associated with high anthers and large pollen, and long style with low anthers and small pollen. These results would seem to suggest that these three characters are all controlled by a single factor pair. This is the position taken by Bateson (1), Gregory (6), and de Winton and Haldane (3, 4) from their studies on *Primula sinensis* in which they found long style to be recessive to short style. Ernst (5), however, working with *P. viscosa* obtained plants in which these characters were present in different combinations. Using these different combinations he was able to show that there was no direct relationship between anther position and fertility. The important feature was pollen size versus style length. That is, large pollen on long style and small pollen on short style produced good seed set whether the anthers from which the pollen came were high or low. From these results he concluded that style length, anther height and pollen size are governed by three different factors, the long-styled, low-anthered and small pollen type being the triple recessive. The results obtained in this study so far do not permit any conclusion concerning this question.

The fact that the two types obtained in this work occurred in approximately equal numbers indicates that one of these types is a dominant heterozygote while the other is a homozygous recessive. As in all species of *Primula* that have been investigated to date (*sinensis*, *auricula*, *hirsuta*, *hortensis*, *viscosa*) the short style condition is dominant while long style is recessive, it is probable that the same condition prevails in *P. obconica*. However, until sufficient numbers of plants have been grown from selfed short style and long style plants this question cannot be definitely answered. As far as practical seed production is concerned this is immaterial unless recombinations should occur which would make the selection of seed plants more difficult.

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Ring Spot on Saintpaulia

By G. H. POESCH, *Ohio State University, Columbus, Ohio*

COMMERCIAL growers of Saintpaulia (*Saintpaulia ionantha*) have had trouble with ring spot which causes bright yellow ring patterns of fantastic design on the dark green leaves. Many reasons for the development of this ring spot have been proposed, such as watering overhead when the light intensity is high, virus disease, improper soil, and high nitrates.

All observed stocks of Saintpaulia have shown this trouble. Many growers are extremely careful in regulating the light intensity but still have trouble with ring spot. Preliminary trials were started to determine the cause of this physiological trouble.

The first trials were carried out in June with the variety Blue Boy. The light intensity varied from 300 to 500 foot candles. The temperature ranged from 62 to 82 degrees F. Four-inch plants were watered overhead each day with tap water (75 degrees F); another similar group of plants was watered with 40 degrees F tap water. The third plot was not watered overhead. The ring spot developed on the plot which was watered overhead with 40 degrees F water.

The second experiment consisted of five subirrigated plots; each plot included 4-inch *Saintpaulia ionantha* and 4-inch var. Blue Boy Saintpaulias. Plot 1 was wet at 9 a.m. with 50 degrees F water; plot 2 wet at 11 a.m. with 50 degrees F water; plot 3 drenched at 11 a.m. with 60 degrees F water; plot 4 wet at 11 a.m. with 70 degrees water; plot 5 no overhead water. Temperatures and light intensity readings were recorded. Plots 1, 2, and 3 showed ring spotting shortly after treatment was started. After several extremely warm days plot 4 showed a few ring spots. Plot 5 did not show any injury.

On August 14 pieces of ice were held a few inches from the leaves and drops of ice-water allowed to fall on the leaf surface. In this case spots were evident in 4 hours. Later experiments confirmed these results; in fact the spots could be seen in the early stages within an hour.

Three light intensities: 1000, 500, and 250 foot candles were selected and two frames for each were constructed by adding muslin to a skeleton frame until all but the desired intensity was excluded. On very bright days a slight excess of light penetrated the screens and on cloudy days very little light penetrated the screen.

Ionantha and var. Blue Boy 4-inch Saintpaulias were placed in each frame. One plot under each light intensity was sprinkled with 75 degrees tap water every day at 11 a.m. Temperature of the air and light intensity were recorded. This experiment began July 27 and continued until August 20 (about 23 days). On August 20 the 75 degrees overhead water was discontinued and 60 degrees tap water drenched on the plots which had not been wet with the 75 degrees water. On September 18 the sprinkled plants were so badly spotted, that further sprinkling was stopped.

None of the plants wet with 75 degrees tap water was found to have developed new leaf spot. Peculiar blotching was evident on the high

light intensity plot which had been sprinkled overhead 2 days with 60 degrees water. These blotches, roundish and later sodden appearing, attained the typical whitish-yellow appearance of *Saintpaulia* ring spot. No rings formed.

Two weeks after application of overhead 60 degrees tap water was started, rings and blotches were noticed on the low intensity (250 foot candles) plot. Several days after the low intensity plot evidenced injury the medium intensity plot evidenced spotting, but not as severely as the two other plots. By the 18th of September the high and the low light intensity plots were completely spotted on every leaf.

On October 7, 1940, two lots were placed in a refrigerator maintained at 50 degrees F. At 11 a.m. every day one lot was sprinkled with 50 degrees F water overhead. The other lot was sprinkled with 70 degrees water every day. Another similar lot was put in the box at 50 degrees for 2 hours, then taken out, sprinkled with 50 degrees water and put back in the *Saintpaulia* house at 11 a.m.

On October 17, 1940, the 50 degrees water was changed to 40 degrees water and an additional similar lot of two plants sprinkled with 40 degrees water without being put in the refrigerator at all.

Apparently there were no injurious effects leading to the development of spot on any of the plots sprinkled overhead with 50 or 70 degrees water. Only the lot not put in the refrigerator developed spot with 40 degrees overhead treatment, and this lot showed severe injury developing 24 hours after the first sprinkling. After the first few days they became so bad the plants were changed and the new lot became spotted again at the same rate.

It was easier to get spotting with 40 degrees water applied on the foliage overhead than when 70 or 50 degrees water was used in the same manner. Precooled plants or plants in a cool place (such as a refrigerator) do not spot as readily as those at a higher temperature even when 40 degrees water is dashed over them. Water at 40 degrees can cause severe injury which is apparent within 24 hours after application as dark irregular areas which later lighten and become typically spotted areas. Further tests with water 40 to 50 degrees higher than the temperature of the plant did not produce any ring spots.

When sulfur dusts were applied to the foliage, ring spots and further bleaching resulted.

CONTROL.

When the temperature of the water was lower than that of the leaf, ring spot developed independent of light intensity. If the temperature of the water was 2 to 5 degrees higher or lower than the house temperature, no ring spots developed even though the light intensity was four times higher than usually recommended for good culture.

To prevent the spots from occurring it is wise to use water only equal to or slightly higher than house temperature when overhead watering of *Saintpaulias* is a necessity. Temperature of the water should be determined, and if it is too cool a suitable heater should be installed. If heating the water is impossible, pot watering should be employed. Watering extremely early in the morning before air temperature increases may also be helpful.

Suggestions for a Course in Fruit Judging

By N. F. CHILDERS, DAVID G. WHITE, and A. E. MITCHELL,
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MOST students develop a special interest in a course in fruit judging. This is particularly true when the course is terminated with a local or interstate contest where cups and medals are awarded. Probably the foremost value of the training is the development of a greater appreciation in the student for fancy fruit, and his ability to identify common varieties of apples, which, in the opinion of many growers, is the first prerequisite in commercial fruit growing.

In most instances where students take part in fruit judging contests there is no college credit given for the training. This was true at Ohio State University until several years ago when the students were allowed to register for the training as a special problem for three credit hours (quarter system). The number of students varied from six to fifteen. The course now is included in the catalogue as Horticulture 606. Fruit Judging, for three credit hours in the autumn quarter. Five to six hours each week are devoted to laboratory study. The course covers the identification of 25 common varieties of apple and the judging of apples in contests, as well as the judging of trays, plates and other forms of display at county and state fairs. Suggestions are given also on methods of selecting and showing fruit at fairs and fruit shows. The course is open to all students in the University and especially those majoring in agricultural education who later are required to coach fruit judging teams for the All-Ohio High School contests. Annually, in January, about 115 teams of three men per team compete in this contest during Farmers' Week. Such a contest serves to stimulate early interest in pomology among these younger boys.

The methods and materials used at this University for teaching fruit judging may not be applicable in other institutions. However, the literature contains so little on the subject that an exchange of ideas may prove worth while.

In the laboratory room, which is 13 feet wide by 25 feet long, there are four heavy-built tables with tops $3\frac{1}{2}$ by 8 feet. The tables stand 34 inches high and are supported on 4- by 4-inch solid wooden legs. As shown in Fig. 1 the tops are covered by heavy duck cloth held tightly in place by half-inch brass stripping around the edges. Beneath the cloth are half-inch felt pads which serve as a cushion for the apples. The cloth is impregnated with three coats of flat white paint upon which the black enamel lines and figures are painted. Two coats of clear floor varnish cover the tops and help to protect the black lines from soap and water and student wear. Four 200-watt drop lights provide adequate lighting for the tables.

The two center tables in Fig. 1 are used for the judging of fruit classes. Each table accommodates 10 classes; the plates are permanently numbered from 1 to 30 on one table and from 31 to 60 on the second table. The rear table in Fig. 1 is used for practice in identification of apple varieties. The table is divided lengthwise by a black line so that there are 54 numbered circles on one side of the line and



FIG. 1. Four specially-built tables are used in the fruit judging course. The two center tables are permanently marked for judging; the rear table is marked for identification exercises, while the fore table contains samples of the twenty-five varieties under study.

54 numbered circles on the other side. The numbers are arranged so that the student passes around the table only once in identifying the 108 apples. Six to eight students can work around the table at one time using special numbered mimeographed sheets and clip boards as shown in the student file cabinet in Fig. 2. If only a half dozen students are present in the laboratory at a time, the instructor

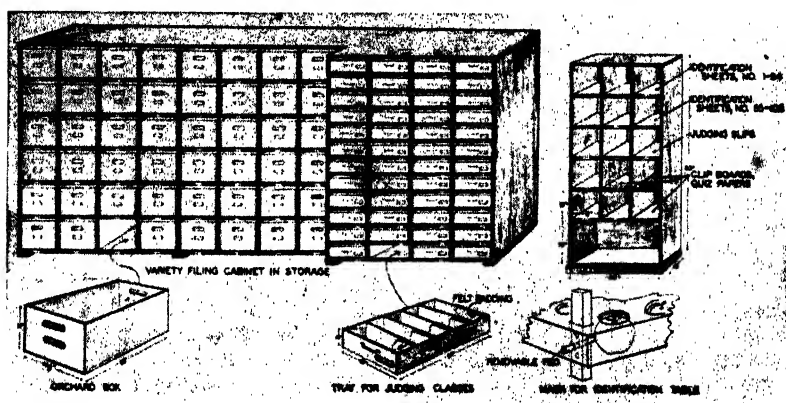


FIG. 2. A large cabinet (left) in the storage affords convenient means for filing plates and variety apples for identification. Small cabinet (right) contains judging and identification forms and return quiz papers. A mask (lower right) reveals only a small portion of the apples for student identification.

can spend 5 or 10 minutes before class laying out the identification apples, and while the students are later identifying them he can spend his time setting up judging classes on the center tables. After the students have identified the apples, the instructor can check their papers while they proceed to judge the half dozen or more classes on the center tables.

The top of the fourth table in the foreground of Fig. 1 is divided into twenty-five 10-inch squares on which are placed groups of four to six apples of the 25 varieties under study. The apples remain available for reference by the students, even while they are taking the identification tests. The apples are renewed on the table once every 2 weeks or as the occasion demands it. Toward the end of the course the exchange baskets of sample varieties from other states are placed on the reference table for 2 to 4 days after which they are moved and placed on the identification table for the student quiz. The state from which the display apples came is indicated by a portable arrow as shown in Fig. 1.

In schools where laboratory space is limited and it is not possible to set aside four specially-built judging tables, another alternative would be to paint the numbers, circles, rectangles and squares on oil-cloth or canvas. The cloth could be cut to fit regular laboratory tables and for each exercise could be thumb-tacked to the table. After the exercise it could be rolled up and laid aside. This procedure would seem more desirable than using chalk on the tables or marked slips of paper to number the apples and classes, as is often done.

Most of the art and carpentry labor shown in Figs. 1 and 2 was furnished by WPA and NYA. However, a Fine-Arts student or some capable person could be employed for the job with money obtained from the laboratory fees. At this University a laboratory fee of \$3.00 is assessed each student who registers for fruit judging. The money is used for buying the temporarily scarce varieties and a dozen or more baskets of specially-picked fancy fruit obtained from nearby growers. Fruit so picked affords a great saving in time and effort on the part of the instructor in selecting classes for judging. Seven to nine reasonably difficult classes can be obtained from one of these specially-picked bushels as compared with only three or four classes from a bushel of average No. 1 packed fruit on the market.

An apple filing cabinet, as shown in Fig. 2, has been constructed in the cold storage for systematically filing the varieties and judging plates. Two labeled pigeon holes are reserved for each of the 25 varieties. The apples are filed in orchard boxes. The right hand side of this cabinet is equipped with 48 trays for filing the judging plates. The trays are about 16 by 24 by 4 inches and are conveniently divided with partitions to accommodate five plates. Instead of dismembering the plates after a laboratory exercise, as is often done, the individual plates are kept intact and filed alphabetically by variety in the cabinet. The No. 1 plates from the classes of a given variety are filed together in one group, as are the No. 2 and No. 3 plates. Thus, it is possible in succeeding exercises to prepare judging classes quickly by jumbling and rejumbling the plates.

The Ohio State Fruit Judging Team is trained primarily for competition in the Eastern Intercollegiate Fruit Judging League. The annual contest is usually held around December 10. This allows for about 8 or 9 weeks of training, beginning the first week in October. The first 3 or 4 weeks are devoted to identification exercises only. One or two new varieties are taken up each period, or about seven varieties per week. Those varieties which closely resemble each other, such as McIntosh and Cortland, are studied together. The most typical specimens are used first, and later the cull pile serves as the best source for identification purposes. When the students feel that they have "completely mastered" the characteristics of the 25 varieties near the end of the course, the identification apples are covered by a mask as shown in Fig. 2. Each mask is large enough to cover about one-third of the table top. The legs at the corners of the mask can be adjusted up or down to fit the size of the apples. When three masks are used at one time on the table, one mask covers the large apples, another the small apples, and the third covers the medium size apples. The student is confined in the identification to only the calyx or stem end of the apple which forces him to study detailed characteristics more closely. An alternative to the mask system is to cut the apples crosswise into halves or thirds and let the students identify the pieces. By the latter system, however, the fruit can be used only once.

In the last half of the course more emphasis is placed on judging, although identification quizzes involving 108 apples are continued each period. At the beginning of the judging exercises only one point, such as condition, is considered at a time and the other four points are disregarded. When significance of condition, uniformity, color, form and size of apples have been introduced separately, the classes are then set up to emphasize primarily but one point, but the student must consider all five points in making his final placing. We have found that this slow introduction of the five points in judging seems to enable the student to grasp them more thoroughly with less conflicting ideas of their relative importance.

The daily student grades for identification and judging are recorded on a bulletin board in the judging room. Summary scores are recorded at the end of each week. The three highest ranking students at the end of the course compose the team, and the fourth highest man is the alternate.

Sermons¹

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USUALLY when I am asked to speak, I am expected to talk about the behavior of some kind of trees. You do not want to hear anything I can say about trees and that fact gives me an opportunity I've been wanting. Perhaps because I am getting so old, I shall take advantage of the kindness of your committee, in asking me to talk without assigning a subject, and shall seek release from a complex that has long been troubling me. When, somewhat more than 40 years ago, I suggested that I might study agricultural science, before there was any, the many (very many) relatives in an extraordinarily prolific and pious family were shocked. For reasons that I do not know, unless it was my exceptional appetite, they had assumed that I would become a preacher. Although I was then determined to branch out in a different direction, I have since wondered if I did not make a mistake. If I had become a successful minister I should have been dealing with a subject that would hold the interest of all these many relatives and most other people. My work in horticulture can be evaluated only by the few of you who know that it doesn't amount to much. I have, therefore, decided to try *preaching* tonight. If I succeed, I shall have the pleasure of knowing that you are pleased, while if I fail, I shall have the benefit of release from any doubts concerning the wisdom of my going against the wishes of my relatives. Under the compulsion of this long suppressed wish to try preaching, I shall take not one text but five, with three or four supplementary texts. Because I always talked too much and am now getting old enough to lose what little restraint I ever had, you may wish, while you are still awake, to select a comfortable shoulder to sleep on.

My first text is in Hawthorne's *Mosses from an Old Manse*: "The lilac-shrubs under my windows are almost in leaf. . . These lilacs are very aged and have lost the luxuriant foliage of their prime. The heart of judgment or the moral sense or the taste is dissatisfied with their present aspect. Old age is not venerable when it embodies itself in lilacs, rosebushes, or any other ornamental shrubs. . . Apple trees, on the other hand, grow old without reproach. Let them live as long as they may, and contort themselves in whatever perversity of shape they please, and deck their withered limbs with springtime gaudiness of pink blossoms, still they are respectable even if they afford us only an apple or two in a season. These few apples or, at all events, the remembrance of apples in bygone years, are the atonement which utilitarianism inexorably demands for the privilege of lengthened life. *Human* flower shrubs if they will grow old on earth should, besides their lovely blossoms, bear some kind of fruit that will satisfy earthly

¹Address given at the Horticulturists' Dinner, at the meeting of the Western Section of the American Society for Horticultural Science at Pasadena, California, June 20, 1941. Printed at popular request and "against the author's best judgment".

appetites, else neither man nor the decorum of nature will deem it fit that the moss should gather on them."

That's a long text but wait till you hear the sermon.

What I wish to emphasize in this first sermon is the fact that we horticulturists are fortunate in both the plants and the people that we work with. I do not necessarily agree with the text that no ornamental plant pleases when it is bent and decrepit. I think many of them do. But the text gives a true impression when it emphasizes the fact that different plants affect us differently, in their vigor and in their decrepitude; in other words, the material we work with has character. The sturdy character and earthy beauty of the apple tree is proclaimed often in literature. Henry Ward Beecher said it is "tough as an Indian, patient as an ox, and fruitful as the Jewish Rachel". Here in California we have another tree, the avocado, that is a more careful lady, but she keeps her schoolgirl figure.

Not only the plants but the crops also have character. Open a package of fruit or vegetables and you see not a mass of *material* but a collection of individuals. I think no one can visit a wholesale market without a thrill of pleasure. Not only are the individual plant impressive in a crate, of that finest product society has been offered in a generation, the Utah variety of celery, even the broken leaves on the sidewalk have character. And preserved horticultural products have also. What has more impressive or forceful character than a dill pickle?

The sturdy dependableness of a tree has been widely used to describe human character. For example in the Song of Solomon, second chapter, third verse: "As the apple tree among the trees of the wood so is my beloved among the sons. I sat down under his shadow with great delight and his fruit was sweet to my taste." We have the privilege of dealing with people having the character that this verse implies. You can't just exist on a farm when you are growing horticultural plants. You must grow them well enough to pay the cost. If there is only one day in spring when the weather permits setting cabbage plants early enough to reach a good market or when spraying will give clean fruit, you must be the kind of man who'll get the work done on that day, or eventually you'll be relieved of the business. In any old orchard or trucking district most of the men left in the business tend to have that dependableness of character, and they are good to be around for other reasons; many people "sit down in their shadows with great delight".

All of us now have the privilege of working with another class of men, the county agricultural agents, whose characters have been tested and strengthened by contact with reality. If one of them suggests a practice to a farmer, he'll be *around* to get the reaction from it; if it isn't sound, town and gown club *talk* will not help. He's dealing with people who are not impressed by such talk. Among the many trials his contact with the workers in different branches of agricultural science causes him to make, there are failures that discipline him against effervescent enthusiasms and yet successes that give him a sound confidence in the value of his work. His intimate contact with many people shows him failures of men he knows to be good farmers and

chance successes of men he knows are not so good and tends to cause him to have a tolerant hopeful view of people generally.

For our research and teaching we must borrow from the technique of other fields, botany and chemistry; in doing so we are again dealing with men whose thinking is disciplined by reality, the reality of the laboratory experiment. Most of them have passed the stage of argument. They know that when there is a difference of opinion the answer can be obtained only by new experiments. They cannot advance their fields, or themselves, by argument or by use of superior, abstruse criticism by showing how both sides of an argument are based on rather stupid thinking, by taking no position, except one of superiority. At least this will not advance botanists or chemists or horticulturists unless their promotion is passed upon by someone who *is* impressed by an air of superiority.

Many problems that laboratory experience would not suggest come to us through the county agents, and laboratory findings are apt to be tested in practice through them. They, as well as we, often obtain suggestions for study and even answers to questions, increases in the body of knowledge in our field, through the experience of men who buy and use unsuitable land such as that on which fruit trees were killed by water this year. In other words, *even the sucker* should have our gratitude. And I'm coming to think that even the man who *catches* the sucker should; in order to emphasize human goodness, *by contrast*, we may need something to *loathe*. The devil has lost his potency for most of us, and Hitler may not *live* always. Some of my friends in zoölogy think we should rather *like* snakes, and I am finding that, at least until you are considerably older than 60 years, you can't *loathe* a skunk effectively for thinking about the irresistible creature its skin will cover next. But no such limitation applies to the man who will take advantage of another's unacquaintance with a situation to sell him land that is unsuited for the use to be made of it or is in two small an area or is ridiculously high priced, or who uses convincing salesmanship to get people onto the land who do not belong on the land, so that a family accustomed to some comforts will be condemned to disappointment, and to *poverty* for life. Such a salesman, especially if he tries to claim some decency by saying, "Well somebody has to get a sucker's money", should produce in us a loathing that by contrast would make average people seem *radiantly* good.

Trees and other plants do not serve merely by producing admiration or as symbols of sturdy character, they seem actually to influence the character of the people who tend them. In Denmark, I was told that a considerable number of graduates of the horticultural schools obtained appointment on the police forces, and that people have come to like them because of their even tempers. Who can say that the ability of Thomas Jefferson to endure such violent criticism and be leader or controlling adviser for so long of the party that he organized may not have been due to the fact that, as frequently as possible, he went back to his farm and pruned and watched his trees and received comfort and encouragement from their sturdy dependableness?

In Sweden the city government of Stockholm ran little experimental

plots to test garden plants for the different soil types so that they could advise the people in the low-cost housing projects in making their homes more beautiful and beneficial. In fact, a man *trained* in a *horticultural school* was in charge of the whole housing project for the city. This seemed to me an appropriate recognition of the relation of plants and plant knowledge to social contentment. The laborers' wives did the gardening. Parenthetically, these Swedish women intrigued me, especially their complexions; they seemed, more than some of ours, to have God's colors, rather than those from a drug store. I wanted to tell them how fine they looked, but I couldn't speak the language. All I could do when I was introduced to one was to hold her hand very firmly and look earnestly into her eyes; but it wasn't satisfactory. In the Scandinavian countries beauty of trees and flowers, including the earthy beauty of fruit trees, seemed to be always associated with efforts for the general good, with effective human love. No houses that we saw, except those completely surrounded by pavement, were without plantings, and only a few in colder parts were without an apple tree. The *highest* expression seemed to me to be the beautiful, new crematory built by the City of Stockholm, in which, for any of its citizens who died, rich or poor, the city showed its regard with beauty of the sturdy architecture enhanced by flowers and trees and rich shadows on a green lawn.

The value of our work to society, however, is measured most largely by the new truth that we supply, by the effectiveness of our research and effectiveness in research is not measured by cleverness with research tools. Research is not merely invention. It is searching a system of knowledge for gaps in it and making carefully planned studies to fill those gaps: convenient access to an uncluttered literature in a field is as important to the worker as a convenient, uncluttered laboratory, if not more important.

The central feature of our work is, of course, the proceedings of our society. In making much use of it lately, I have become proud of it. I believe the members are learning to report their work to one another more briefly and effectively than any other group I follow somewhat except the chemists. I do not need to emphasize the convenience and better editing that would follow if all horticultural research could be reported in the proceedings: the convenience of finding all research in a field in one volume or series of volumes is obvious. By better editing I do not mean better correction for English usage. I mean better editing to avoid cluttering the literature with unnecessary pages of discussion or unnecessary details of data. This can be done only by a man acquainted with the field and can be done with less danger of causing ill feeling if the editor is away from a man's own institution. The data belong, I believe, not to the institution that supported the research, but to the people who need them in their studies: all research institutions are merely units in a great cooperative enterprise — the building of systems of knowledge. I believe that by being unselfish enough to recognize this relationship and buying space in such society publications as the proceedings, instead of publishing in their own isolated, inconvenient, and overpadded series, experi-

ment stations would be doing a great service toward the advancement of agricultural science, by getting reports of research to workers in a form that makes them more apt to be read, and by saving 75 to 90 per cent of their printing costs for use in the *conduct* of research. But that would conflict with the prestige of the individual experiment stations and of some of their workers.

This brings me to my second text. I am sorry that I cannot quote it precisely; but, anyway, Napoleon Bonaparte is reported to have said that there are *rattle boxes* for people of all ages and all levels of culture.

The *supreme rattle box* in university life, I think, is prestige. Appropriately, the word is from a French word meaning juggler's tricks. For the sake of this major rattle box we have all other rattle boxes such as extravagant, inconvenient publication series, honor societies that distract people's attention from useful activities, and honorary degrees that mislead the public into thinking that some men, or supermen, connected with a university have the wisdom to select, usually from fields with which they are not acquainted, men who deserve honors above their fellows. Usually, I believe, if a man can be known to deserve an honorary degree, his merits are so well known that the degree does him no good. If his merits are not so well known, the degree may be a blunder or a lie. For ten years I had the privilege of being connected with an institution that gave no other degrees than those which indicated that some teachers believed the recipient had demonstrated the gifts and acquired the training for work in their fields. That freedom from shams seemed good to me. Other institutions seem to select, for honorary degrees, local people who have done exceptionally useful public work, quietly. The motive back of this is certainly good. But I wonder if either the man or the work is benefited by the publicity. Some universities seem to me to select only men already smeared with prestige, apparently hoping that in the process of catching them and tying degrees onto them, some of their prestige will rub off onto the university.

With prestige made such a supreme goal we might expect the standards for obtaining it to be at least as high as that for obtaining such an earthly thing as money. And yet, if you take money that belongs to someone else you are apt to be punished for it, but if you take credit for work planned and done by someone under you, you may be rewarded for it, may even get an *honorary degree*. Some men were once talking about a man who had an offer at another institution. He was noted for taking credit for everything done by anyone he could get into his laboratory, sometimes for work he had nothing to do with, sometimes even for work he could not read understandingly. One man said the university would be lucky to be rid of such an old burglar, but another said, "No, the university is anxious to keep him for the prestige he brings". However, in spite of such conspicuous examples, most men get credit for what they do, and among most actual workers the standard of integrity in this regard is high.

A more serious matter is the piling up of equipment to display your scientific aspirations when other people need the money for equipment

to use. Unnecessary expenditures for equipment cannot be obtained without impeding research in the institution; for there is never enough for all good workers. For this reason, a loyal scientist will be *ashamed* to show equipment or equipped rooms before he can show at the same time well planned work in progress in them. Yet sometimes equipment seems to be obtained and used only to display a man's cleverness in devising it. This may be very effective for him if he shows it only to influential men on his campus who know nothing about his field. To be severely honest he would have to say when displaying it: "I really should use this, too, in spite of the fact that other equipment I have keeps me busy; for some other men in this same building need the money badly for equipment they would use."

However, I believe that much the most harmful seeking after prestige is that which wastes the time of the workers by forcing them to get published data they need from isolated, cumbersome, inconvenient publication series and makes it possible for the same data to be published in several different articles. Besides the fact that laws obtained by grafting printers in some states prohibit the use of state money for printing outside the state, the arguments given by a committee of experiment station directors against buying space in journals concerned prestige, private and institutional: they were afraid someone would obtain priority over someone else who had his paper written first, as if scientists of today care who gets into print a few days the sooner; and they were afraid the experiment stations would lose some credit, as if prestige were more important than service. A lot of fun can be had by officials thinking up expensive ways to make an experiment station technical series seem distinctive. The California experiment station has a special technical series that, in harmony with the sham that proclaims a series of unrelated technical papers a journal, publishes papers by different authors or on different subjects under one expensive cover. If you receive one of these jumble bags and think you'll ever want to find the articles again, you tear the cover off, tear the two or three papers apart and file each separately where it belongs in a system, swearing meanwhile because the staples cut your hand. I swear also because I know where the money for the useless cover is needed badly for research.

The title counters: the people who count titles rather indiscriminately in determining promotion, tempt workers, especially young workers who are hard pressed for a living, to publish prematurely; or even worse, to make use of the experiment station series and overlapping journals to publish the same data in several papers with slightly different titles and discussion.

And *that* leads me to my third text which is from Mark Twain, who once said, "I have long had a great reverence for a goat: after all the publishers had refused my first story, I offered it to a goat, and he accepted it." To protect our proceedings against the effects of the title counters, I believe this society should have a goat; a journal run only for the purpose of supplying titles to be counted. It would cost us some money, but I believe we could charge it to entertainment, spend less money for moving pictures and still have more fun. In preparing

meaningless papers with titles and texts that use scientific terms, I think the more clever ones should help the others, so that each member would have the same number of titles and no injustice would be done, at least to *members of this society*. Of course we could not call our journal "The Goat"; that would garner no prestige. But if we should call it *capra hircus* of the family Bovidae, prestige would cover our heads like forests cover the mountains, or like weeds cover an old feed lot.

My fourth text is from the Bible, Ecclesiastes, third chapter, 22nd verse: "Wherefore I perceive that there is nothing better than that a man should *rejoice* in his *own work*, for that is his portion: for who shall bring him to see what shall be *after* him." Unlike much of the Bible, this text does not emphasize as the highest good, man's desire for comfort and prestige after death, and it emphasizes no personal relationships but offers peace through *loyalty* to our *work*, or to the cause that it supports. Loyalty to a cause is a most dependable sustaining influence. As Dr. Josiah Royce says: "I may serve my cause ill. I may conceive it erroneously. I may lose it in the thicket of world transient experience. My every human deed may involve a *blunder*. My mortal life may seem one long series of failures. But I know that my cause liveth."

For *purely selfish* reasons no man can *afford* to be *selfish*. And for his own good, as well as for the good of society, a wise man will refuse to support a practice that benefits his *family* or his *friends* or the *local institution* that *supports* him, if that practice is detrimental to the *general* cause that his work represents. Loyalty to be a dependable support in the confusing problems of life must be applied to something *too big* to be blamed for *failures*. Persons and *institutions* that are administered by persons are too apt to disappoint our expectations of them: too much affection for them may bring disaster. Thomas Hardy uses hard, chiseled tragedy to emphasize human character much as the landscape architect uses smooth lawns to emphasize the beauty in his structures and in his trees and shrubs. In one of his books, *The Woodlanders*, while the catastrophe is approaching through the frailty of a daughter that a selfish father loves with savage intensity, Hardy interposes the generalization that the father's love for a *single person*, with her exposure to the *overpowering influences* of life, was too engrossing to be safe in this world.

Our work serves the sturdiest people in our national life and serves them wisely through men that live close to them; and it joins with that of other natural scientists who are attempting to make the path of humanity *safe* with the *light* of *truth*. No one has work more deserving of loyalty. And I believe that if the time comes when a reader of our Proceedings finds all data in our subjects reported there and can find no papers that give evidence of being written only because the author wanted his expenses paid to a meeting, no data that are reported also in other journals or in experiment station technical papers, and no discussions that are included for any other reason than that they are needed by other workers in the field, that reader will be justified in concluding that the members of the society are controlled

by a *comforting loyalty* that makes them *not only* better workers in their fields but also better *companions* for their families and their friends and better servants of the institutions that support them.

For my fifth text, to emphasize again the virtue of the material we work with, I am going to the Scandinavian literature. I believe that Brother Leo expressed a great truth when at the beginning of an incomparably beautiful sermon he said: "*Philosophy* divides people; *literature* unites them". And I believe that by holding a *mirror* to life, in such a way as to disclose all classes of people to each other, their ways of life, their aspirations, and their conflicts with nature, the Scandinavian fiction writers have increased the determination in those countries to insure a reasonable degree of comfort to everyone who wishes to work. Among these writers Bjornsen seems to have the greatest faith in human goodness. My text is at the end of his book, *In God's Way*. After distressing conflict between a minister and his sister and a free-thinking but upright husband, they come together in bereavement and conclude that, "How good people walk, that is God's way". I think we can say, "How all people and all things walk: that is God's way". I do not believe any evidence justifies our thinking that God has any preference for man over snakes, codling moths, or red scales. I think any improvement in man's position must come from his own group instinct supported by loyal, patient intelligent effort. On the other hand, I do not believe that a thing ceases to be a work of God or to be interesting because it found its present position through the agency of man instead of wind, birds, or beasts. For a walk, I suggest the city street in preference to the virgin forests. The plants you see may not be growing where some bird dropped the seed, but they may have been brought first to England a century or two ago by explorers on sail boats, possibly with a greenhouse on a rough deck and tended by sailors who were *about as natural as birds*; and these plants have been tried by thousands of people and found to thrive and to give pleasure. Of course, you may not go far before you find pruning atrocities on a shrub that, left alone, has a natural grace that makes it almost sacred to gardeners with an understanding of beautiful form; you may find such a shrub sheared into a globe or a cylinder. You may want to stop and ask the owners why they don't achieve a similar effect and save the cost of the water and the gardener and avoid insulting the plants by hanging up the wash tub or setting a rain barrel against the house; but of course, anyone who can say, "My gardener," with just the right emphasis would never have a wash tub, or at least would never admit it.

Walking in a modern city, however, you would miss the good old earthy helpfulness of village women giving advice from their back doors. "O, Mrs. Mallory, your pigs is in the house." "Thankin' ye, Mrs. Hennessy, but whose business is it, where my pigs is?" "O beggin's y'r pardon, Mrs. Mallory, but I didn't think ye'd want y'r pigs to get dirty." But you *would* probably see the tired business man coming home. "I'm late again dear. I've had my nose to the grindstone all day." "Yes, dear, I know you couldn't get home any sooner, but for days like this when we're having company for dinner, couldn't you

have a grindstone that doesn't smear face powder and lipstick all over your clothes?"

And you couldn't afford to miss seeing Joe Evans, the agent of a company that sell supplies to certain public service activities. He is just home from a successful trip and is now surveying his garden with rather stiff, pompous approval, without touching any plant. His *gardener* attends to that, but Joe gives the orders. In his expense account he can include several hundred dollars a month for expenses entertaining customers, and he has enjoyed it. Joe is convinced that there's nothing like alcohol to improve the understanding of customers. He has contempt for government effort to promote employment. Never was a time when anybody who really wanted work couldn't get a job. Just look at him; started with nothing. And this aid to the farmers. Let 'em work hard and use initiative like farmers used to. His grandfather supported eight children on a farm and sent them to college — at least all who were willing to go there and work for their board and clothes and tuition. They'd have that farm in the family yet if his brother had farmed it right and kept it from being sold for the mortgage. Even California *fruit growers* are taking government aid. Nonsense. It's a bonanza for anybody who'll work and manage well. He knows: he used to sell fruit land. Charged them enough to make them look at it as a business and to keep them from trying to farm too much. Five acres is enough. He bought ten. Too much. He'd have made it go, though, if he'd had time to give it his attention. This federal home loan! Bunch of grafters in his opinion. Wouldn't give him a loan because he wouldn't make a lot of improvements. Has to pay more interest. Wouldn't have needed the loan on his place if he hadn't been trying to keep that fruit farm. Ought to have let it go *sooner*. Joe's garden is as well groomed as he is. And the trees sheared just as round.

Joe's charming young daughter gives him more help in spending the returns on his entertainment allowance than toward paying off the mortgage on the house. She accepts most of these returns as God's recompense to the glamorous, or to those who wish to be glamorous, and is not conscious of a labor problem or of a farm problem. She is completely urbanized, unless it is an obscure influence of her farmer ancestry that causes her to paint her lips to look like grandfather's red barn doors.

If you are taking a leisurely walk in the city streets about seven o'clock in the evening and hear a tinkling, carefree laughter, like that of young girls, you'll be wise to stop and introduce yourself. You'll be welcome and invited to dinner, especially if you have a tenderness for the plants you will be shown. The person who welcomes you, however, will not be a young girl but a woman somewhat over fifty who spent her girlhood in Alsace. The laughter came when she saw cheerfulness come back into her husband's face on their daily round, seeing her plants before dinner. All day long after he leaves early in the morning and after she has done the housework, she works in her garden, whenever she plants something, saying a prayer to the old home garden and her impoverished people in Alsace, and when it grows, as it always does, feeling that she has been answered by them. Her husband comes

home late, gloomy from overtime work drafting new designs for airplanes that may be used to kill his people somewhere in Europe; but before long her plants and her *spirit*, the essence of the flowers she has worked with all day, have prepared him for a jolly dinner of incomparable food that she has prepared and serves. As often as not there will be guests who will go home probably with rooted cuttings from some of her plants and certainly with the feeling that to be in such a garden home *once* makes life worth while.

In such an early evening walk you may pass the modest home and the earthy natural garden of a lawyer who graduated with enthusiasm for the crusade against public corruption that was most successfully advertised by Theodore Roosevelt. During the depression he learned that corruption of public officials is not what causes the greatest amount of insecurity and poverty; something he does not understand is to blame. He has continued to fight for whatever seemed to him better ways of life, calling it liberalism until he lost his faith in catchwords. He has had to fight entrenched people who could use billboards and other means of publicity to oppose him and his associates and who have *cleverly* trained whisperers to work against him. Members of his family are not interested in his reforms and wish he would spend more time making money at his law practice. Some of his associates have not been too trustworthy, and the people he has tried most to help do not seem to have much interest in the general good. He hasn't even found *himself* too trustworthy; why did he let the pressure of a campaign force him to join with corrupt leaders? And now the *war* is obscuring *all* issues. Will the people settle back to corruption and shiftlessness?

He takes off his stiff office clothes, dresses for his garden, and goes out with his pruning shears like Thomas Jefferson. He finds only a few shoots here and there that can stand shortening in. His lawn is greener than it was yesterday, and he will have to cut it soon. He doesn't edge it up much but pulls the spreading grass from among his flowers and shrubs occasionally. Buds are breaking everywhere; all his new plants are growing; some had looked doubtful till now; most of the grafts he set last winter are growing, too. His funny looking apple tree, mostly Winter Banana but with branches of four or five other varieties that do even worse than Winter Banana in this climate, has some of last year's leaves and new leaves opening, fruit ripening in an abnormal sort of way and blossoms opening. Grafts of two other varieties he set on it this year are breaking their buds. It is a poor, gnarly, little tree, but as he looks at it a picture of the great apple trees in his boyhood home comes before him. He pulls one of the rusty little fruits and enjoys it as he did green apples in the old days. He wonders if he is *fair* in thinking that people are not interested in the general good. His wistaria buds are fuzzy tassels, every bud to give a cluster of flowers. What else can be so dependable and yet so graceful as wistarias? He admires his trumpet narcissus that are in their golden prime, wonders how anything so evanescently beautiful can still give the impression of such sturdiness. In this climate most people would plant a gaudy flowering tree in the best position on the place, but he has a pine tree, thinks it has a sturdier, more reassuring beauty; every

bud on it is now a gray-green pencil. He sits down under it and begins to think about Thomas Jefferson and the collections of fossil bones he kept in a room in the White House. Wonders what man's ancestors were like when they first branched off from the line that produced him and the apes and what they were like for the long time afterward before they began to leave their marks around. Thinks of the many troubled periods since and human progress in spite of them. And, then, the smell of the pine tree in his nostrils and new confidence stirring him, he springs up with his old-time vigor : now if never before there must be something he can do. His experience, even his mistakes should help. During all this destruction of the *beaten* paths, unselfish, thoughtful effort by many such experienced people should enable men to find a *new* path that will become God's *better way*.

Influence of the Environment on the Expression of Hereditary Factors in Relation to Plant Breeding¹

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ENVIRONMENTAL influence on the expression of hereditary factors has many aspects. To the geneticist this is the cause of non-hereditary variation. To the experimental taxonomist it helps to explain the status of geographic races. To the breeder it may represent the opportunity to provide adaptability. To the horticulturist interested in cultural problems, differential varietal response to the environment is being increasingly recognized as an important factor in making cultural recommendations. Each aspect has as its fundamental basis the response of the hereditary factors or genes, either singly or more commonly in groups, to the many conditions external to the organism, under which it develops. These outside influences are usually rather complex and difficult to control experimentally. Those most frequently studied are temperature, light intensity and duration, soil and air moisture, wind movement and a variety of nutritional factors. This obviously is more than can be encompassed in detail in a single discussion. For this reason only enough work will be reviewed to indicate their bearing on plant breeding in the South.

One of the first careful studies of the effect of the environment on the expression of the gene was made by T. H. Morgan (50) and reported by him in 1915. A strain of *Drosophila* was found in which the abdomen was defective. This was shown to be sex-linked and to be due to a single mendelian factor. The remarkable thing about it was that only the flies that hatched while the colony was young had the defect, while flies emerging later were normal in every respect. By suitable tests it was shown that flies developing from larvae whose food had been moist had the defective abdomen, while flies whose larval stage was spent on drier food were normal. Much later Braun (10) discovered another strain that developed an abnormal abdomen on dry media, while flies from larvae on moist food were normal. These instances illustrate two points that should receive emphasis. (a) The expression of a gene of known genetic behavior can be influenced by the environment, in this case moisture, to produce adults differing widely in appearance, and (b) under appropriate conditions of the environment the individuals of a special genetic strain can not be distinguished from the type taken as normal.

A second component of the environment that has received considerable attention from the geneticists working with fruit flies is temperature. Zeleny (86) in 1923 showed that an increase of 1 degree C during the larval stage decreases the number of facets of bar eye by 10 per cent, of ultra-bar by 8 per cent and of normal flies by 2.5 per cent. He pointed out that the same effect can be obtained either by

¹Address of the retiring chairman of the Southern Section of the American Society for Horticultural Science, given at the Memphis meeting, February 7, 1942.

increasing the temperature or by adding another bar gene. Surrarrer (72) secured an increase in mottling in a mottle-eye stock by decreasing the temperature from 24 to 18 degrees C. Flies developing at 24 degrees or above are normal with respect to this character.

The effect of temperature on the development of various bristles has been studied by several investigators. Plunkett (58) found that in general an increase in temperature results in a reduction in the number of bristles. He considered that the effect is due to the acceleration of a bristle inhibitor with increased temperature at a greater rate than the normal bristle former. Child (14, 15) discovered that an increase in temperature decreases the mean number of some bristles but increases the number of others. The effect of temperature, then, depends upon the genotype. Each type has its optimum temperature for bristle formation. A change of temperature gives a differential effect on the rate of reaction of the various gene-controlled bristle forming and bristle inhibiting substances.

A number of genes for defective wings of *Drosophila* have been studied. Harnly (32) found that the effective temperature for increasing the wing length of vestigial is between 30 and 32 degrees C. Eker (19) states that flies homozygous for genes for short-wing are normal at 14 degrees but have typical short wings at 27.5 degrees. This factor also affects the size of the eye. Jennings (39) mentions a gene in *Drosophila* for extra legs at cool temperatures.

Passing on to another insect, the Hymenopterous parasite of the oriental fruit moth, *Trichogramma minutum* consists of several morphologically similar races that carry different factors for body color which are entirely dependent upon an appropriate temperature for their expression. According to Peterson (57) when the average daily temperature exceeds 62 degrees F the females of one race have a distinct lemon yellow body color, but when the temperature drops below this average these same individuals become a metallic brown. Flanders (23) finds that four races of this parasite can be identified on a basis of color when raised at the same temperature, but when raised at different appropriate temperatures they are indistinguishable. Temperature with this insect not only affects body color but also influences the length of the life cycle, an important character in determining adaptability to climate.

This whole problem of the role played by temperature in the expression of the genes and gene combinations in insects has been given especial attention by Goldschmidt (28, 30) who has developed a theory of gene action through physiological processes that may be hastened or retarded differentially at various temperatures. He has been able to produce intersexes in the gypsy moth in this way, and he has modified the appearance of certain butterflies to correspond to various geographic forms. He lists no less than 14 known genetic characters of *Drosophila* that can be induced by suitable heat treatment of the normal larvae.

The effect of temperature on the expression of hereditary factors is by no means limited to insects. In Canna, Honing (37) finds that the anthocyanin pigment producing "old purple" is recessive to another

factor for yellow. Plants that are homozygous recessive for old purple and heterozygous for yellow (ssWw) are completely yellow during the heat of summer, but later flowers of the same plant developing during cool weather in the fall have a bluish cast. *Primula sinensis* has a form in which the flower is red at 20 degrees C, but white at 30 degrees. A genetically distinct type has a white flower at both temperatures. Barnes (6) and also Magruder and his associates (43) report that the carotene content of carrots develops best between 60 and 70 degrees F, less color developing either above or below this optimum range. R. C. Thompson (76) secured more intense anthocyanin color in lettuce at temperatures below 50 degrees. In the case of the tomato fruit Vogeles (83) gives 24 degrees C as the optimum temperature for the formation of lycopene. Fruits developing at 32 to 38 degrees are bright yellow and they remain green at 40 degrees. Work in Texas and elsewhere suggests that factors exist in the tomato that permit the normal development of red color at temperatures as high as 35 degrees.

H. C. Thompson (73, 74) has studied the influence of temperature on flowering. He secured differential response of celery varieties subjected to temperatures below 50 degrees F to induce seed stock formation. The effect of low temperature on the flowering of biennials depends upon (a) the temperature employed, (b) length of time exposed, (c) stage of development, (d) kind of plant, (e) photoperiod, and (f) later growing conditions. All of us are familiar with the necessity of many fruits and ornamentals for cold during the dormant period in order to bloom and fruit normally in the spring. Varieties differ widely in their cold requirements. The use of cold in vernalization treatments to hasten fruiting would seem to be a variation of this same theme.

The bearing of these differential responses of plant varieties to heat or to cold on the problems of plant breeding may not be immediately evident to those who handle plants in an environment for which their crops have long been bred or selected. Once these plants are grown outside of their accustomed environment the necessity for hereditary factors that will permit them to grow and produce as an economic crop are soon apparent.

The same may be said of the responses of plants to light. The literature concerning the reactions of plants to photoperiod has become rather extensive. The interest of southern plant breeders in this subject arises from the shortness of the days experienced during both summer and winter compared to the day-length of the normal growing season farther north where many of our commercial varieties were developed. Allard and Garner (1, 26, 27) in joint reports have shown that some plants require a relatively long day to flower, others need a fairly short day and still others seem to be relatively independent of this influence. These authors suggest that the lack of flowering observed in numerous introduced plants may be due to an unfavorable photoperiod. The manipulation of the length of day is sometimes desirable to bring two types of plants into flower at the same time in order to make a cross, as was done by Emerson (20) with teosinte.

Sometimes other types of development affected by the light period are of economic importance. For example, only four varieties of onions will bulb properly during the short day of the extensive commercial onion areas of Texas. Both McClelland (46) and Magruder and Allard (42) have found that only Bermuda will bulb satisfactorily with 12 hours of daylight. The work of Breslavac (11), McPhee (49), Schaffner (69, 70) and others on hemp shows that length of day has an important bearing on sex expression. Intersexes and sex reversal can be induced in hemp by providing a short day. A similar effect was obtained by Richey and Sprague (63) with corn. Several inbred strains responded differently to changes in day-length. Allen (2) points out that "environmental factors can influence the expression only of potentialities genetically present. If a once pistillate plant is induced to produce staminate flowers, the results show that genetic factors are present which make possible the production of stamens."

The effect of photoperiod is often conditioned by temperature. Knott (41) found that cooler early temperature and warmer late temperature with a 15-hour day favored seed stalk formation in spinach. Either continued low temperature or a 7-hour photoperiod restricted blossoming. Lettuce heads best at 60 to 70 degrees F according to Thompson and Knott (75) and will not head from 70 to 80 degrees even with a short photoperiod. Roberts and Struckmeyer (64, 65) find that temperatures above and below the normal change the photoperiodic response of many plants. Poinsettia blossomed normally for them in the winter at 60 to 65 degrees but did not at 68 to 70 degrees, or between 55 and 57 degrees. In the summer it bloomed at the last named temperature.

They (66, 67) later report that certain seedling populations of petunia and other plants gave a uniform response with respect to growth and flowering under one temperature and photoperiod but showed "segregation" under other conditions. They ascribe this to genetic differences that are not apparent under one set of conditions but do appear under other conditions. Since varietal differences of this kind are common, there seems to be no a priori reason why this explanation might not be accepted. In fact this falls directly in line with other work. The only difficulty in accepting it lies in the fact that similar "segregation" was observed among cuttings obtained from the parent of the seedlings. It may be that differences in the initial size of the cuttings and some lack of uniformity in their handling resulted in variability among the cuttings grown under abnormal conditions of temperature and photoperiod that would simulate differences due to genetic diversity. Further work would seem to be required to establish these assumptions.

Often environmental factors other than or in addition to temperature and light make a significant contribution to the appearance or behavior of a plant. Brainerd and Peitersen (9) found that light intensity, humidity, altitude and moisture supply greatly affect the characters of wild blackberries that have been widely used in their classification. For example, the leafy bracts and prickles develop much better in a cool moist shady place than in full sun. The pungency of onions is

another such character. Platenius and Knott (58) found that onions on peat are twice as pungent as those grown on sand, and onions on loam are intermediate in this respect. Pungency tends to increase with increased temperature. More sulfur in the soil increases pungency but more soil moisture decreases it. In spite of these environmental effects, with comparable conditions, some varieties are three times as pungent as others.

Available sugars inside the plant are an important factor in the formation of anthocyanin pigmentation. Environmental factors influencing the accumulation of sugars therefore affect plant color. These include soil nutrients, light, temperature, water, available nitrogen and altitude. Owen (54) reports increased mottling of soy bean seeds on heavy, rich soil, and sometimes with wider spacing, while increased nitrogen decreases mottling. A similar situation has been found with respect to the amount of pigment in the seed coat of field beans (55). Ratsek (62) has been able to reduce the intensity of color of red roses to nearly white by defoliation and by pruning away carbohydrate reserves.

Work on the manipulation of a multitude of cultural factors has now assumed enormous proportions. It is all based on the assumption that the complex of hereditary factors affecting growth and yield are influenced in their expression to a considerable degree by the environment. The differential response of varieties to identical treatments has been mentioned. Attention is called to a few cases among both plants and animals where a change of nutrition has affected a single character or some otherwise striking result has been obtained.

To return to *Drosophila*, the vermilion brown stock lacks the amount of eye pigment of normal flies. When the 70-hour larvae are placed on a partial starvation diet the intensity of color is greatly increased. It is estimated that this treatment stimulates the production of the eye color hormone by "not less than a hundredfold" (7). In studying a stock of the bent nose Norway rat in which about half of the individuals had this defect when fed a home made diet, Heston (35) was surprised to get only normal rats when the stock was placed on Purina Fox Chow. It was found that a certain calcium-phosphorus ratio and vitamin D do not allow genes for bent nose in the rat to express themselves.

Work on the effect of nutrients on the fruiting of plants has produced rather striking results. Many fungi, as you know, are induced to produce sexual spores on artificial media only with great difficulty or not at all. Sax (68) grew field beans with white and with colored seed coats on rich and on poor soil. Factors linked with color gave the higher yield under unfavorable conditions, while factors linked with white seed gave a higher yield under favorable conditions. Similar results were secured by Poehlman (60) with two varieties of soybeans. The Morse variety outyields Virginia on fertile soils and good growing conditions, while Virginia produces more than Morse under less favorable conditions.

The effect of differences in soil reaction is sometimes rather striking; for example the blue or pink flower color in *Hydrangea*. Buxton

and Darbshire (13) have investigated the behavior of anthocyanins at different hydrogen-ion concentrations. There are two main groups. The blue group is "lake red" at pH 3 and blue at pH 7. The red group is vermilion red at pH 3 and changes to a brownish purple at higher concentrations. Purple or magenta flowers contain both types.

A somewhat different type of effect of environment on gene expression is found in its influence on disease resistance. Walker and Smith (84) report a decreased resistance of commercial varieties of cabbage resistant to yellows, with increased soil or air temperature to 28 degrees C. It would seem that both host and pathogen might share in this measurable response in their relationship. Andrus and Wade (3) have secured a significant difference in resistance of a cross between Corbett Refugee and Geneva Red Kidney bean to anthracnose in the greenhouse and in the field. In fact a segregating F_2 gave a ratio of 14:2 in the greenhouse and 15:1 in the field at Beltsville while a 15:1 ratio was obtained with a comparable F_3 population in the greenhouse at Charleston. They conclude that "environment is an especially important factor in anthracnose reaction where certain genotypes are involved", and further "It would seem to be self evident in the field of plant breeding that any vegetable as highly developed and interbred as, for example, tomatoes, melons, peas and beans would possess extreme inter-varietal heterogeneity in respect to genotypes . . ."

For plant breeders faced with problems of adaptability, as many of us in the South and West are, a good deal of the work in experimental taxonomy has a direct bearing on our problems. It makes no real difference whether the features that fit a plant for a particular environment are inherited under other conditions or not. Whether the valuable characteristic represents an "environmental variation" from what may be considered the normal type elsewhere, or represents a new genetic combination that can maintain its individuality under other conditions makes a difference only if the climatic conditions the plant breeder faces are so variable that the usefulness of the so-called "environmental variation" is nullified. One of the difficulties in discussions of this kind is the almost universal human error of assuming that the familiar is the only true norm and that all other forms are "off-type". This suggestion obviously has its limitations, as the normal tends to be the modal type, and environmental variation as observed in the laboratory or under field conditions tends to be continuous. In the widest sense, distinct forms resulting from the interaction of a genetic complex with contrasting environments, do have genetic meaning both for the taxonomist and for the plant breeder.

The problem of adaptation among both wild and cultivated plants is a matter of finding genes whose expression under a particular set of conditions favor growth and maintenance. The essential differences in the two cases lie in the numbers of individuals involved, in the methods of selection, and to no small extent in the economic motivation of the breeder. A better understanding of the processes of nature should be of value to the latter.

An important method in the experimental study of taxonomy is the transplantation of clonal divisions of different forms to a common

environment or to several types of environments and noting differences in behavior. These have been of several kinds. Turesson (77) moved geographic races of a good many European species to a single garden. Some geographic varieties remain distinct when grown together, in other cases they are indistinguishable, showing that geographic types may or may not be the result of differences of genetic expression under different environments. Turesson stresses parallel varieties among geographic races of unrelated species when growing under the same climatic influences. He finds that a widely distributed species may have a special alpine type in one group of mountains but not in another where it also grows. He suggests that this may result from the loss of genes producing the alpine type from the species in one area but not in another. Thus occurrence of geographic races may be due either to environmental influence on gene expression or to the natural selection of genetic segregates or complexes that have special adaptive value. Clausen, Keck and Hiesey (16) list a number of plant characters unaffected by a change of climate. These include habit of branching, density of inflorescence, leaf shape, venation and texture, the character and density of pubescence, anthocyanin in the stems, flower size, shape and color, and seed-size and color. Where differences were observed, "Nearly every morphological character was found to depend upon a small series of genes, each of minor but cumulative effect." Traits having adaptive value such as time of flowering, frost resistance etc. also have a genetic basis.

Vavilov (80, 81, 82) has developed the idea of parallel variation among geographic races and species, calling this the "law of homologous series in variation". He suggests that where plant breeders observe adaptive characteristics in species related to the material they are working with, there might be a reasonable chance of finding or developing the character from their own or the more closely related wild material. The crossing of distinct geographic races may make it possible to transcend the limit of ordinary types.

Turesson (78) refers to the work of Massart (45), which I have not had an opportunity to consult, as an example of very marked response of a single genotype to different environments. *Polygonum amphibium* readily adapts itself as a land plant, a water plant or a dune type merely by growing divisions of a single individual under these distinct conditions. Each one would be considered a definite geographic race, which is the normal type for each environment.

In discussing the origin of genes responsible for well adapted climatic races Goldschmidt (29) credits Davenport and Cuénot with the suggestion that genes useful in a new environment arise by mutation and may be carried along by chance until they have an opportunity to express themselves and contribute to the survival of the species under the new conditions. This has been called preadaptation. He even goes so far as to say ". . . we must regard such preadaptational mutations as a prerequisite for the spreading of a species into new areas with different conditions, which would be inaccessible to the original form . . ." White (85) discusses the possibility of the existence of genes for cold hardiness among tropical species and those having a

southern range. He cites the case of a native Texas pecan that was found to be fully hardy in Canada. Three species of *Iris* native to Texas proved to be hardy in New York. Occasional mutations for hardiness in tropical plants are likely to be lost if there is no change of climate to give them selective value.

Students of these problems realize that not just one gene may be involved in the genetic-environmental situation that determines the appearance and behavior of plants and animals, but whole groups of genes. The effective number of genotypes with which a worker can deal will depend upon the proportion of genes and gene combinations in any population that give a distinctive response to different environments. Bruman (12) has discussed this situation with respect to plant introduction. He observes that a change of climate may provide an opportunity for the expression of genetic factors that were entirely recessive in the old environment. Such changes may be of advantage or disadvantage either to the plant or to the breeder. He points out that the Navel orange is better in California than in either Florida or in its homeland, Brazil. It might be added that the pink-blush grapefruit appears to develop better color in Texas than in Florida. It is likely that most of the bud mutations of this type have been brought to light in Texas on this account. There is no reason to suppose that the rate of mutation is any higher in Texas than in Florida, although the larger number of Marsh trees in Texas may help to explain the situation.

There may be a lesson for the plant breeder in Fisher's theory of the origin of dominance (21, 22). He supposes that most mutations originally have some effect in the heterozygous condition, that is they are partially dominant to their wild type allele. As this effect is unlikely to be beneficial to the organism, any combination of genetic factors tending to cover up the effect of the new gene will have survival value and eventually this will become the normal wild type with the new gene fully recessive. Such a complementary effect might be made use of by the plant breeder in outcrosses of valuable but not fully adapted material to secure new genetic combinations that favor the development of the desired characteristic under a particular set of environmental conditions. The value of such a method will depend entirely upon the material available. It should be remembered that the breeding situation among crop plants is different from that among wild species both in the matter of the effective number of breeding individuals and in the basis of selection. The opportunity for crosses with wild types in many instances permits the incorporation of such recessive genes in the plant breeder's stocks. For example it seems likely that certain useful genes for fruit color and perhaps other characters may have been introduced incidentally in transferring factors for wilt resistance from *Lycopersicon pimpinellifolium* to *L. esculentum* (8, 61). It has even been suggested (4) that "... mutations which are pathological in one gene-complex may be harmless or even advantageous in another, and such effects are open to the influence of selection."

Dobzhansky (18) states that the survival of recessive genes in wild species depends a good deal on the size of the effective breeding popu-

lation. The smaller the population, the less chance there is for the survival of genes having no selection value. Since the effective breeding population in most plant breeding work is extremely limited, we infer that hereditary factors of especial value for a particular area are frequently lost when the actual breeding and selection are done outside of that area.

Babcock (5) raised seedlings of wild tarweeds in the garden and noted wide variation the first year affecting plant size and habit, flower structure and color, size and pubescence of leaves, and other characters. Additional types were secured through subsequent selection and inbreeding. He points out that many of these variations are "types of abnormality common among species long domesticated". Hill (36) recounts a similar experience during the domestication of *Primula malacoides*. During its first 4 years in cultivation varieties were established that involved an increased size of corolla, a flower color range from white to "deep mauve", double flowers, corolla shape, scent of the foliage and vegetative vigor. These variations parallel those of other species of *Primula* long in cultivation.

Some of the most important characteristics the plant breeder interested in adaptability has to deal with may be classed as physiological. Nilsson-Ehle (53) found that an apparently uniform variety of wheat would become more resistant to cold through the natural elimination of those individuals with genetic factors for tenderness. McKinney and Sando (48) have crossed spring wheat, which requires long warm days with winter wheat, which first needs cool short days. In order to classify the segregation in the F_2 they found it necessary to grow populations both in the spring and in the fall. In discussing the theoretical basis of vernalization McKinney (47) emphasizes that physiological response is conditioned by the genetic constitution of the plant and that "... dominance and segregation ratios in many characters must be considered within well defined environmental limits ..."

Heyne and Laude (34) have tested the resistance of inbred lines of corn to high temperature in the laboratory, securing differential response that checks with field experience. They conclude that "the testing of seedlings for heat resistance can be relied upon with considerable assurance for distinguishing genetic differences in the drought tolerance of larger plants of different strains of maize. Hawthorn (33) has been able to select lines of Bermuda onions less apt to split and double. The point of chief interest to us in connection with this work on wheat, corn and onions is that varieties that are to all appearances entirely uniform, do carry valuable hereditary factors that can express themselves only under suitable environmental conditions. As far back as 1911 Hagedoorn (31) advised that in crosses to secure drought resistance, tests for resistance should be restricted to the F_2 as any recessive factors might be lost in a susceptible F_1 . The suggestion applies with equal force to crosses for disease resistance due to recessive factors.

Considerable information is available in regard to general responses of crop plants to changes of the environment. For example, Flory and Walker (24) found that the cabbage head tends to be longer in

proportion to width under southern as compared to northern conditions. Darrow and Waldo (17) report that the Missionary strawberry is earlier than Klondike in the South with relatively long winter days but is later in the North with short winter days. The genotype conditioning the response of the strawberry to day-length can only be determined by growing selections under different environments.

The effect of environment on the behavior of corn has received considerable attention. One of the early studies was made by Ness (51) in 1898 who grew several varieties of field corn at Ithaca, New York and at College Station, Texas. When grown at College Station most varieties were slightly later, shorter, had more suckers, longer, thicker ears, and a larger number of ears. Jones and Huntington (40) suggest that "the yield per acre is highest near the northward limit of possible cultivation". This may be partly due to adaptability, partly to the elimination of some of the common pest of corn by the cold winters. Mangelsdorf (44) reports that some varieties as Surcropper and Ferguson Yellow Dent have wide regional adaptability in Texas while others have very narrow limits for high production. Similarly some varieties as Mexican Junc have wide seasonal adaptability. Pearl and Surface (56) ascribe the regional adaptability of varieties of corn to the hereditary factors that have accumulated in any one variety. Credit for developing races of corn having genetic factors permitting the adaptability of races to widely different environmental conditions is given by Jenkins (38) to the American Indian.

Before drawing the moral for plant breeders inevitable to such a discussion as this let us review briefly some of the points that have been made: (a) single mendelian factors that have been studied genetically have been found to vary widely in their expression because of differences in environmental conditions; (b) under one set of conditions it may be impossible to distinguish between distinct genetic types while under other conditions they may be quite different in appearance; (c) factors of the environment that are responsible for these differences include moisture, temperature, light, nutrition and many geographic and cultural conditions that affect these things; (d) there must be appropriate environmental conditions before any gene or combination of genes can have selective value, either natural or in plant breeding, otherwise they may be entirely lost; (e) in tests, suitable conditions may have to be provided artificially; (f) the cumulative effect of modifying factors under a particular set of environmental conditions can be taken advantage of by the plant breeder in improving the adaptability of selections having special market appeal; (g) the value of any heritable character under a particular set of conditions bears no relation to its development or lack of development under other environmental conditions; (h) work in experimental taxonomy encourages the belief that the adaptability of many crops for southern and southwestern conditions can be materially improved by breeding and selection even though they have been developed primarily for other regions with quite different conditions; (i) genes of value in one area may be lost by breeding elsewhere, improvement might be expected in some cases through intervarietal crosses by accumulating

genes from different varieties that may have a favorable effect directly or in combination; and finally (k) in other cases more rapid progress may be expected by outcrossing to wild forms where these are available or by making wide crosses among cultivated forms. Perhaps this summary carries its own moral.

As a matter of fact much of the breeding work in the South and Southwest has been and still is in line with these considerations. The United States Regional Vegetable Breeding Laboratory at Charleston, South Carolina, sends out segregating strains of vegetables to permit selection of the most favorable genetic combinations for each local condition, which does indeed vary widely in the region served by this laboratory. The Alabama Station has for years collected varieties of vegetables that have attained special local adaptability through selection for perhaps several generations in home gardens. Miller's selections of strains of vegetables especially adapted to conditions in Louisiana and Potter's selections of productive tung oil trees follow these principles. The program at the United States Horticultural Field Station at Cheyenne, Wyoming includes the collection of strains of horticultural plants adapted to the Southwest, many of them grown and perhaps developed by the Indians of that vast area. T. V. Munson was highly successful in crossing commercial varieties with selections of the native grapes of Texas and many of the standard varieties now grown were produced in this way by him. The work of Ness (52) in crossing the wild dewberry with the cultivated raspberry, and of Drain with raspberries for the South are also of this type. The most successful varieties of plums in Texas represent crosses between selections of native species and Japanese and European varieties. The current breeding program with fruits and vegetables at the Texas Station is based on these considerations.

The renewal of interest in breeding for increased adaptability to southern conditions evident in the past 10 years is very encouraging. As the work progresses we may expect an even larger accumulation of hereditary factors favoring quality and production under our conditions. This will make it increasingly easy to synthesize a variety according to certain specifications. There is still a good deal of spade work to be done. This means that we must discover new genes, *judging their value to us not by their expression under a different environment, but by what they can do under conditions peculiar to our own locality, both as individual hereditary factors and in new combinations*. With these it seems reasonable to expect that we can provide the plant material basis for an increasingly prosperous southern horticulture.

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